ESSAY

At the Intersection of Histories

Technology and the Environment

JEFFREY K. STINE and JOEL A. TARR

When is a trend a trend? In July 1997 *Technology and Culture* devoted a full issue to the theme of technology and the environment. The five articles that made up the issue—and that, as the editors noted, had arrived unsolicited at more or less the same time, making their focus on the single broad theme of the environment seem serendipitous and thought-provoking—ranged from the legacy of industrial pollution to technological design choices and landscapes to debates over natural and artificial foods.[1] Although a first for *Technology and Culture,* other historical journals had recently published special issues on the reciprocal interplay of technology and the environment. What seems clear, however, is that the history of technology, which emerged as a professional pursuit some four decades ago, and environmental history, which has existed as a field of study for approximately half that long, have finally begun to generate sustained attention to those gray areas where the two fields overlap.

It can be difficult to write environmental history without paying at least passing attention to technology. Conversely, it can also be difficult to write technological history without touching on some environmental element. A review of environmental history and the history of technology uncovers numerous superficial references to the intersections of technology and the environment, but until recently this relationship has seldom constituted the

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1. The articles, which appeared in *Technology and Culture* 38 (July 1997), included Hugh Gorman, "Manufacturing Brownfields: The Case of Neville Island, Pennsylvania"; Eugene Levy, "The Aesthetics of Power: High-Voltage Transmission Systems and the American Landscape"; Warren Belasco, "Algae Burgers for a Hungry World? The Rise and Fall of Chlorella Cuisine"; J. Morton Briggs, "Pollution in Poullaouen"; and Edmund Newell, "Atmospheric Pollution and the British Copper Industry, 1690–1920."

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principal focus of concern. This is not to suggest that past historians have published nothing of substance on this topic; the historical interaction of technology and the environment has always attracted some scholarly attention.[2] Lewis Mumford, for instance, was writing about the effects of technology on the urban environment in the 1930s, and expanded on that theme in his later work.[3] In 1956, the then fledgling National Science Foundation (NSF) sponsored a pathbreaking international symposium titled "Man's Role in Changing the Face of the Earth." This symposium, held at Princeton University, resulted in a thousand-plus-page tome whose authors plumbed the vast variety of humankind's past and present technological manipulations of nature.[4]

Scholars of American studies had begun to explore the nexus of technology and the environment nearly a decade before *Technology and Culture* came into existence. Henry Nash Smith articulated a central theme—technology in the garden—in his landmark 1950 work, *Virgin Land.* His ideas were extended by a trio of equally provocative studies: Leo Marx's *The Machine in the Garden* in 1964, Marvin Fisher's *Workshops in the Wilderness* in 1967, and John F. Kasson's *Civilizing the Machine* in 1976. To be sure, these authors did not necessarily agree upon the power or content of the "myth of the garden" or of the concepts of "nature" as they confronted American technology. Nor did they concur about the character of the interaction, but together they produced a powerful framework that allowed subsequent scholars to assess the widespread environmental implications of technology.[5]

2. In his field-defining *Bibliography of the History of Technology* (Cambridge, Mass., 1968), Eugene S. Ferguson included a brief section titled "Human Ecology and Natural Resources." Among the seventeen eclectic works cited—most not written by historians—were Gordon T. Goodman, ed., *Ecology and the Industrial Society: A Symposium of the British Ecological Society* (New York, 1965); Stewart L. Udall, *The Quiet Crisis* (New York, 1963); Sam B. Warner Jr., *Streetcar Suburbs: The Process of Growth in Boston, 1870–1900* (Cambridge, Mass., 1962); and Lynn White jr., "The Legacy of the Middle Ages in the American Wild West," *Speculum* 40 (April 1965): 191–202. Although Ferguson showed foresight in identifying a promising area of investigation, he was not outlining an integrated, established body of literature.

3. See, for example, the following publications by Lewis Mumford: *Technics and Civilization* (New York, 1934); *The Culture of Cities* (New York, 1938); "The Natural History of Urbanization," in *Man's Role in Changing the Face of the Earth,* ed. William L. Thomas Jr. (Chicago, 1956); *The City in History: Its Origins, Its Transformations, and Its Prospects* (New York, 1961); and *The Highway and the City* (New York, 1963).

4. William L. Thomas Jr., ed., *Man's Role in Changing the Face of the Earth* (Chicago, 1956).

5. Henry Nash Smith, *Virgin Land: The American West as Symbol and Myth* (Cambridge, Mass., 1950); Leo Marx, *The Machine in the Garden: Technology and the Pastoral Ideal in America* (New York, 1964); Marvin Fisher, *Workshops in the Wilderness: The European Response to American Industrialization, 1830–1860* (New York, 1967); and John F. Kasson, *Civilizing the Machine: Technology and Republican Values in America, 1776–1900* (New York, 1976). Leo Marx now concentrates on ecological questions. See,

During the late 1960s and early 1970s, several prominent members of the Society for the History of Technology (SHOT) issued wake-up calls about the importance of environmental considerations. It was no coincidence that they wrote just as social critics began denouncing modern technology for exacerbating the nation's pollution problems. Lynn White jr. published his provocative essay "The Historical Roots of Our Ecological Crisis" in 1967, which immediately stirred up controversy far beyond the halls of academia.[6] In a 1969 commentary in *Technology and Culture,* A. Hunter Dupree urged an ecological perspective that understood technology as humankind's principal means of adapting to and altering the environment.[7] Two years later, Nathan Rosenberg explored the "nature of the technology-environment problem" from an economic perspective, outlining both the positive aspects of technology and its negative side effects, or "externalities."[8] In his 1975 anthology *Changing Attitudes toward American Technology,* Thomas Parke Hughes emphasized that America's growing environmental problems had dampened public attitudes toward technology. He argued that society's previously positive view of technology as a progressive force for controlling a hostile nature had shifted to an overriding concern that technology had forged a not altogether beneficent artificial world.[9] Even SHOT's longtime secretary and journal editor, Melvin Kranzberg, pointed to the ecological dimensions of technology.[10]

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for example, his "The Domination of Nature and the Redefinition of Progress," in *Progress: Fact or Illusion?* ed. Leo Marx and Bruce Mazlish (Ann Arbor, Mich., 1996); and "Technology: The Emergence of a Hazardous Concept," *Social Research* 64 (1997): 965–88.

6. Lynn White jr., "The Historical Roots of Our Ecological Crisis," *Science* 155 (10 March 1967): 1203–7.

7. A. Hunter Dupree, "Comment: The Role of Technology in Society and the Need for Historical Perspective," *Technology and Culture* 10 (October 1969): 528–34. Of Dupree's first four doctoral students, three—James L. Penick, Morgan B. Sherwood, and Donald C. Swain—went into conservation history, while only one, Carroll W. Pursell, went into the history of technology.

8. Nathan Rosenberg, "Technology and the Environment," *Technology and Culture* 12 (October 1971): 543–61. See also Nathan Rosenberg, *Technology and American Economic Growth* (New York, 1972), 186–201. For an extended economic analysis of industrialization's environmental impacts, see Richard G. Wilkinson, "The English Industrial Revolution," in *The Ends of the Earth: Perspectives on Modern Environmental History,* ed. Donald Worster (New York, 1988).

9. Thomas Parke Hughes, ed., *Changing Attitudes toward American Technology* (New York, 1975). In contrast, the other standard history of technology anthology of the period, Edwin T. Layton Jr., ed., *Technology and Social Change in America* (New York, 1973), virtually ignored environmental variables, except for brief mentions of pollution concerns by Herbert J. Muller in his chapter, "Human Values and Modern Technology," and by the editor himself in his introduction.

10. See Melvin Kranzberg, "Environmental Problems and Technology," *Environment and Culture* (English translation of Japanese title) 12 (October 1974): 2–9; and

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In spite of the stature of these scholars, none of their writings inspired historians of technology to focus their research on the past effects of technology on the environment.[11] Neither did the environmental activism and legislation of the 1960s and 1970s generate such continuing scholarly investigation. With the controversy surrounding the publication of Rachel Carson's *Silent Spring* in 1962, the extensive press coverage of ecological disasters such as the 1969 Santa Barbara oil spill and the 1971 Birmingham smog episode, and the nationwide celebration of the inaugural Earth Day in 1970, however, historians could not easily ignore society's growing concern about technologically induced environmental hazards. International events such as the Vietnam War and the energy crisis drew additional attention to the harm that technology could inflict upon nature. With the publication of his 1971 best-selling critique of America's environmental crisis, *The Closing Circle,* biologist Barry Commoner provided a series of historical case studies—along with an intellectual structure for further examinations—of how the technological choices made since 1940 were largely responsible for the severity of the country's pollution problems.[12]

Many historians of technology had deep personal concerns about these issues. Most probably believed that technology, as an active human force, had at its heart the manipulation of nature for humankind's ends. Then why the limited attention in their research to this basic theme and why the recent burst of attention illustrated in table 1? As Arthur McEvoy noted in his perceptive treatment of the workplace environment, technology is "the point of interaction between the human and the natural." As he explained it, "technology is what distinguishes human activity in nature from that of other animals; because technology is a means of interacting with nature,

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"The Ecological Implications of Technology Transfer," in *Fourteenth International Congress of the History of Science, Japan* (Tokyo, 1975). He later expanded upon these themes in his 1985 SHOT presidential address, making several references to how historians of technology should address environmental considerations. See Melvin Kranzberg, "Technology and History: 'Kranzberg's Laws,'" *Technology and Culture* 27 (July 1986): 544–60.

11. Although historians of technology were slow to pick up on this theme, the interaction of technology and the environment quickly became an important area of study within the science, technology, and society (STS) programs that emerged during the 1970s. See, for example, Ian G. Barbour, *Technology, Environment, and Human Values* (New York, 1980); Ian Barbour, Harvey Brooks, Sanford Lakoff, and John Opie, *Energy and American Values* (New York, 1982); Marcel Chotkowski LaFollette, "Of Bottles, Pitons, and Reaching for New Directions," *Environment* 25 (December 1983): 9–11; and the relevant articles, reports, and bibliographical entries that appeared frequently in the pages of *Science, Technology, and Human Values.*

12. Barry Commoner, *The Closing Circle: Nature, Man, and Technology* (New York, 1971). For his assessment of the environmental regulations of the 1970s and 1980s, as well as an extension of his critique of technologically induced ecological problems, see Barry Commoner, *Making Peace with the Planet* (New York, 1990).

TABLE 1

NUMBER OF CITATIONS, SELECTED TOPICS, *TECHNOLOGY AND CULTURE* ANNUAL BIBLIOGRAPHY OF CURRENT PUBLICATIONS IN THE HISTORY OF TECHNOLOGY

	1962–65	*1966*	*1967*	*1968–69*	*1970–71*	*1972–73*	*1974–75*	*1976–77*	*1978–79*	*1980–81*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*
Air Pollution			1				3	4	5	1	2				1	1		4	6	1		6	4	5
Antinuclear Movement																	2	16	6	3	5	3	4	1
Conservation Movement	4	1																1	1	3	10	10	9	9
Ecology	2				2	3	4	5	3	2														
Environment													2	1	7	8	4	23	22	30	51	59	59	50
Environmental Movement												2	2	1							17	15	10	21
Forests and Forestry	1	3			3	2	1	13	6	3	8	6	4	10	15	15	29	43	17	27	81	52	69	49
Health, Occupational																	2	5	4	6	9	8	7	3
Human Ecology																		3	4	17	9	10	9	6
Land Use/ Utilization	8	1				3	1							1							13	19	18	26
Natural Resources			1				1						1					4	1	1	3	3	8	4
Pest Control																	1	2	2	1	1	1	3	3
Pollution							1			1					2	1		4	4	3	5	2	16	5
Public Health					5						1		1		1		1	3	1	6	15	7	8	3
Radiation								1								1	1	1	3	5	7	1	2	6
Risk Assessment											1									1	7	1	1	10
Waste Disposal/ Removal													1	1	1		2		2	1	15	2	6	5
Water Pollution						1		3	1									1		1	5	5	3	2
Total	15	5	2	0	10	9	11	26	15	7	12	8	11	14	27	26	42	110	73	106	253	204	236	208

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however, it should be amenable to ecological analysis."[13] One can argue that historians of technology have a social responsibility to write about environmental concerns because their training and insights into technology—which is one of the principal ways that human communities relate to the environment, for good and ill—offer special understanding. But even without a social responsibility, historians of technology ought to be motivated intellectually, since impacts upon nature are one of the chief results of the increasing dependence of society upon technology.

The historical examination of technology and the environment makes sense on several levels. First, it is extremely fertile scholarly ground, allowing researchers to gain fresh insights, address problems from different perspectives, and ask probing questions. Second, it reflects an existing trend within the historical subfields, in which scholars in environmental history, the history of public health, and the history of technology are increasingly finding common ground. Finally, it reflects actual shifts in the real world, where environmental science and technology are more consciously and systematically addressing the interface of technology and the environment. Technology has helped shape and mold human life, just as nature has done. And, conversely, humans have influenced the character and development of both technology and nature. The history of technology therefore has much to gain from increasing the number of its studies in environmental areas. As the noted environmental historian Donald Worster wrote in 1990, "Wherever the two spheres, the natural and the cultural, interact with one another, environmental history finds its essential themes."[14] Because technology is a cultural expression, its intersection with the natural sphere creates a subfield of environmental history, just as this intersection creates a subfield of the history of technology.

This essay surveys what has been written about the historical interactions of technology and the environment during approximately the last quarter-century and explores the areas of overlapping interest between technological and environmental historians. This task is not as straightforward as it may seem, since many works evade precise classification. Moreover, some studies that explore technologies and environmental change do not bring technology to the forefront. That is, technology is dealt with as a black box, with little consideration given to its design or to the possible alternative technological choices. Likewise, some fine technological histories mention environmental factors but thereafter treat them as mere backdrop. Given its space limitations, this essay cannot hope to be

13. Arthur F. McEvoy, "Working Environments: An Ecological Approach to Industrial Health and Safety," *Technology and Culture,* supplement to vol. 36 (April 1995): S150.

14. Donald Worster, "Toward an Agroecological Perspective in History," *Journal of American History* 76 (March 1990): 1090.

comprehensive; instead, it focuses on the areas of scholarship where the nexus of technology and the environment has produced a strong body of historical literature or where there remain unexpected gaps. Rather than attempting the impossible task of citing every relevant work within the areas covered, we present what we consider the best or most representative research. The interactions of technology and the environment know no political, cultural, or geographical boundaries, of course, yet the size constraints of an essay led us to restrict our investigation to works dealing with the United States. That was no easy decision, especially in light of the excellent scholarship appearing all around the world.[15]

A review of the past literature reveals numerous authors who have touched upon the interactions of technology and the environment, but few who have pursued the topic directly. In his 1990 assessment of trends within the history of technology, John Staudenmaier highlighted this historiographic shortcoming when he lamented that, apart from a few exceptions, "there has been virtually no serious study of the historical relation-

15. For examples of research that bears upon some aspect of the nexus of technology and the environment outside the United States, see Richard P. Tucker and J. F. Richards, eds., *Global Deforestation and the Nineteenth-Century World Economy* (Durham, N.C., 1983); Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900–1900* (Cambridge, 1986); Bill Luckin, *Pollution and Control: A Social History of the Thames in the Nineteenth Century* (Bristol, England, 1986); Robert W. Harms, *Games against Nature: An Eco-Cultural History of the Nunu of Equatorial Africa* (Cambridge, 1987); John MacKenzie, *The Empire of Nature: Hunting, Conservation and British Imperialism* (Manchester, 1988); John F. Richards and Richard P. Tucker, eds., *World Deforestation in the Twentieth Century* (Durham, N.C., 1988); Joel A. Tarr and Gabriel Dupuy, eds., *Technology and the Rise of the Networked City in Europe and America* (Philadelphia, 1988); Jean-Pierre Goubert, *The Conquest of Water: The Advent of Health in the Industrial Age* (Princeton, N.J., 1989); J. M. Powell, *Watering the Garden State: Water, Land, and Community in Victoria, 1834–1988* (Sydney, 1989); Peter M. Haas, *Saving the Mediterranean: The Politics of International Environmental Cooperation* (New York, 1990); Clive Ponting, *A Green History of the World* (London, 1991); Stephen J. Pyne, *Burning Bush: A Fire History of Australia* (New York, 1991); Daniel Faber, *Environment under Fire: Imperialism and the Ecological Crisis in Central America* (New York, 1992); Madav Gadgil and Ramachandra Guha, *This Fissured Land: An Ecological History of India* (Delhi, 1992); Elinor G. K. Melville, *A Plague of Sheep: Environmental Consequences of the Conquest of Mexico* (Cambridge, 1994); Warren Dean, *With Broadax and Firebrand: The Destruction of the Brazilian Atlantic Forest* (Berkeley, 1995); Michael D. Bess, "Ecology and Artifice: Shifting Perceptions of Nature and High Technology in Postwar France," *Technology and Culture* 36 (October 1995): 830–62; Chad Gaffield and Pam Gaffield, eds., *Consuming Canada: Readings in Environmental History* (Mississauga, Ont., 1995); Richard H. Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860* (Cambridge, 1995); Lane Simonian, *Defending the Land of the Jaguar: A History of Conservation in Mexico* (Austin, Tex., 1995); Richard C. Hoffmann, "Economic Development and Aquatic Ecosystems in Medieval Europe," *American Historical Review* 101 (June 1996): 631–69; and Dale H. Porter, *The Thames Embankment: Environment, Technology, and Society in Victorian London* (Akron, Ohio, 1998).

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ship between technology and the environment." Although perhaps exaggerated for effect, Staudenmaier's observation was nevertheless fundamentally true.[16] That situation was already beginning to change, however, as manifested by various institutional developments. In 1983, for instance, the U.S. Army Corps of Engineers Historical Division, which had long sponsored histories of the agency's various district and division offices, launched its Environmental History series, with the publication of Martin Reuss's study of the corps's new environmental advisory board.[17] In 1991, under an NSF grant, SHOT and the History of Science Society organized a Conference on Critical Problems and Research Frontiers in the History of Science and History of Technology, in Madison, Wisconsin, which included a session called "Technology and the Environment."[18] Recognizing the emerging interest in this subject, the University of Akron Press established its Technology and the Environment series in 1992.[19]

16. John M. Staudenmaier, "Recent Trends in the History of Technology," *American Historical Review* 95 (June 1990): 724. In backing this statement, Staudenmaier identified only two articles from *Technology and Culture*—Joel Tarr et al., "Water and Wastes: A Retrospective Assessment of Wastewater Technology in the United States, 1800–1932" 25 (April 1984): 226–63, and John G. Burke, "Wood Pulp, Water Pollution, and Advertising" 20 (January 1979): 175–95—as exemplifying the study of technology and the environment. Although clearly not a well-developed, thematic research area within the history of technology, several other articles in *Technology and Culture* addressed that subject. Among them were Rosenberg, "Technology and the Environment" (n. 8 above); Louis P. Cain, "Raising and Watering a City: Ellis Sylvester Chesbrough and Chicago's First Sanitation System," 13 (July 1972): 353–72; Louis P. Cain, "Unfouling the Public's Nest: Chicago's Sanitary Diversion of Lake Michigan Water," 15 (October 1974): 594–613; William H. Te Brake, "Air Pollution and Fuel Crises in Preindustrial London, 1250–1650," 16 (July 1975): 337–59; John H. Perkins, "Reshaping Technology in Wartime: The Effect of Military Goals on Entomological Research and Insect-Control Practices," 19 (April 1978): 169–86; Carlos Flick, "The Movement for Smoke Abatement in 19th-Century Britain," 21 (January 1980): 29–50; Suellen Hoy, "The Garbage Disposer, the Public Health, and the Good Life," 26 (October 1985): 758–84; and J. Samuel Walker, "Nuclear Power and the Environment: The Atomic Energy Commission and Thermal Pollution, 1965–1971," 30 (October 1989): 964–92.

17. Martin Reuss, *Shaping Environmental Awareness: The United States Army Corps of Engineers Environmental Advisory Board, 1970–1980* (Washington, D.C., 1983). Subsequent titles included Jeffrey K. Stine and Michael C. Robinson, eds., *The U.S. Army Corps of Engineers and Environmental Issues in the Twentieth Century: A Bibliography* (Washington, D.C., 1984); and Raymond H. Merritt, *The Corps, the Environment, and the Upper Mississippi River Basin* (Washington, D.C., 1984).

18. The three papers in this session included Michael Smith, "Ratings First! Earth Later! Media Depictions of Environmental Issues"; McEvoy, "Working Environments" (n. 13 above); and Jeffrey K. Stine, "Engineering a Better Environment."

19. The University of Akron Press's Technology and the Environment series, edited by Jeffrey K. Stine and William McGucken, has issued five titles to date: Jeffrey K. Stine, *Mixing the Waters: Environment, Politics, and the Building of the Tennessee-Tombigbee Waterway* (1993); James Rodger Fleming and Henry A. Gemery, eds., *Science, Technology, and the Environment: Multidisciplinary Perspectives* (1994); Joel A. Tarr, *The Search for*

The increased scholarly attention to the historical interaction of technology and the environment was reflected in several other ways, including an increase in the number of papers addressing technological themes at the biennial meetings of the American Society for Environmental History (ASEH) and the appointment of a SHOT liaison to ASEH, expressly to encourage jointly sponsored sessions at the societies' meetings.[20] In the spring of 1994, ASEH's journal, *Environmental History Review,* published "Technology, Pollution, and the Environment," a special issue that included articles on chemical, coke, and metals industry pollution, and on the relationship between sanitary engineering and industrial hygiene.[21] At almost the same time the *Journal of Urban History* released its own special issue, "The Environment and the City," which specifically addressed the historical interplay of technology and the environment.[22] Confident that this subject would appeal to their students, the University of Virginia established a Committee on the History of Technology and the Environment in 1997, which planned graduate study, undergraduate minors, and a seminar series.[23]

These emerging signs of interest have varied widely in their scope, intent, and impact, but taken together they suggest the possibilities of this

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the Ultimate Sink: Urban Pollution in Historical Perspective (1996); James C. Williams, *Energy and the Making of Modern California* (1997); and Porter.

20. Those themes have been encouraged by three recent chairs of ASEH's biennial meeting program committee, each of whom happened to have a special interest in the history of technology: Martin V. Melosi in 1991; Joel A. Tarr in 1993; and Jeffrey K. Stine in 1997. Stine served as SHOT's first liaison to the ASEH from 1991 to 1996, when Lynne Page Snyder succeeded him.

21. See Joel A. Tarr and Jeffrey K. Stine, guest editors, *Environmental History Review* 18 (spring 1994): 1–116. The articles included Jeffrey K. Stine and Joel A. Tarr, "Technology and the Environment: The Historians' Challenge"; Joel A. Tarr, "Searching for a 'Sink' for an Industrial Waste: Iron-Making Fuels and the Environment"; Franz-Josef Bruggemeier, "A Nature Fit for Industry: The Environmental History of the Ruhr Basin, 1840–1990"; Christopher Sellers, "Factory as Environment: Industrial Hygiene, Professional Collaboration and the Modern Sciences of Pollution"; Craig E. Colton, "Creating a Toxic Landscape: Chemical Waste Disposal Policy and Practice, 1900–1960"; and Lynne Page Snyder, "'The Death-Dealing Smog over Donora, Pennsylvania': Industrial Air Pollution, Public Health Policy, and the Politics of Expertise, 1948–1949."

22. Christine Meisner Rosen and Joel A. Tarr served as guest editors of this special issue of *Journal of Urban History* 20 (May 1994): 299–434. The articles included Christine Meisner Rosen and Joel A. Tarr, "The Importance of an Urban Perspective in Environmental History"; Christopher Hamlin, "Environmental Sensibility in Edinburgh, 1839–1840: The 'Fetid Irrigation' Controversy"; Andrew Hurley, "Creating Ecological Wastelands: Oil Pollution in New York City, 1870–1900"; Martin V. Melosi, "Sanitary Services and Decision Making in Houston, 1876–1945"; and Adam W. Rome, "Building on the Land: Toward an Environmental History of Residential Development in American Cities and Suburbs, 1870–1990."

23. Edmund Russell (assistant professor in the University of Virginia School of Engineering and Applied Science) to Joel A. Tarr, 4 March 1997.

line of scholarly inquiry. To explore the intellectual developments in this area, we will address six broad topics: history of technology textbooks; cities and the environment; public health and occupational health and safety; industry and manufacturing; natural resources; and environmental policy and politics.

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Textbooks

In their now classic 1967 textbook, Melvin Kranzberg and Carroll Pursell asserted that existing histories of technology typically had omitted the "cultural, economic, social, and other interrelationships of technology." They maintained, however, that because technology "is nothing more than the area of interaction between ourselves, as individuals, and our environment, whether material or spiritual, natural or manmade," it should be studied in its widest aspects. Kranzberg and Pursell addressed this imbalance by commissioning essays on the societal effects of the industrial revolution and the interrelationships of technology to social change. Topics within sections titled "Materials and Structures," "The Food Revolution," and "Land Use and Resources" included water supply, sewage disposal, chemical pesticides, land use, and conservation. Although water pollution attracted a passing account, environmental problems associated with air pollution, land pollution, and solid waste disposal were all ignored. No single chapter focused on the environment or pollution, and few essayists attempted to weigh the ecological effects of specific technologies.[24]

The Kranzberg and Pursell volumes dominated textbook publishing in the history of technology until 1980, when Paul W. DeVore published his survey on the evolution of technology and its relationship to society. DeVore included a section on technology and the environment within his chapter "Human Problems and Political Issues." In it he argued that the "use of new kinds of technology on a global scale is the source of greatest environmental concern" and proceeded to outline several contemporary pollution problems. He paid little attention, however, to technology's ecological impacts during earlier times.[25]

24. Melvin Kranzberg and Carroll W. Pursell Jr., eds., *Technology in Western Civilization,* 2 vols. (New York, 1967). See especially Aaron J. Ihde's chapter, "Pest and Disease Controls," and J. L. Penick's chapter, "The Resource Revolution," in vol. 2. Although somewhat episodic in his presentations, Pursell extended these forays into the technological dimensions of environmental history in two subsequent anthologies: Carroll W. Pursell Jr., ed., *Readings in Technology and American Life* (New York, 1969), 264–80; and Carroll Pursell, *From Conservation to Ecology: The Development of Environmental Concern* (New York, 1973), passim.

25. Paul W. DeVore, *Technology: An Introduction* (Worcester, Mass., 1980), 304–9. Although aimed at a different audience than that for the history of technology textbooks discussed in this section, Joseph M. Petulla's *American Environmental History: The*

In 1981, Carroll Pursell edited a collection of biographical profiles of leading figures in American technological history. Two sketches, Ruth Schwartz Cowan's essay on scientist Ellen Swallow Richards and Samuel P. Hays's portrait of conservationist Gifford Pinchot, encompassed environmental topics. Cowan emphasized Swallow's contributions toward improving women's lot through domestic science and home economics rather than her contributions to sanitary engineering and "euthenics," but the latter two disciplines had a greater environmental tie. Hays observed that Pinchot had used science and technology to manage the national forests for commodity goals but that those same tools could have been used by forest managers to advance environmental quality. He argued that just such a shift in the application of science and technology, toward improving environmental factors and away from the simple facilitation of commodity production, distinguished the environmental movement of the post–World War II period from the earlier conservation movement.[26]

In their 1989 survey of American technology, Alan I Marcus and Howard P. Segal advanced beyond previous textbooks in their consideration of technology and the environment. They explored such topics as "systematizing nature," engineers and the environment, and the use of technology in the nineteenth century to exploit and transform the physical landscape: "[M]ost citizens reserved their true passion for nature, [not] pure wilderness." Following the lead of Hays, they discussed the conservation movement, placing it under the rubric "political control of nature." They also examined how engineers responded to the critiques of technology popularized during the 1960s and 1970s. Gary Cross and Rick Szostak followed a similar tack in their 1995 textbook, *Technology and American Society,* which incorporated brief examinations of the ecological consequences of technology. Cross and Szostak began by describing the destruction of North American forests by

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Exploitation and Conservation of Natural Resources (San Francisco, 1977) remains one of the few environmental history surveys to explicitly incorporate the perspective of the history of technology. In providing an overview of the exploitation of natural resources in the United States, Petulla maintains that industrialized economic development contributed directly to mounting pollution levels, ecological disruptions, and the depletion of various natural resources. For his extensions of this argument, see Joseph M. Petulla, *American Environmentalism: Values, Tactics, Priorities* (College Station, Tex., 1980); and *Environmental Protection in the United States: Industry, Agencies, Environmentalists* (San Francisco, 1987).

26. Ruth Schwartz Cowan, "Ellen Swallow Richards: Technology and Women," and Samuel P. Hays, "Gifford Pinchot and the American Conservation Movement," both in *Technology in America: A History of Individuals and Ideas,* ed. Carroll W. Pursell Jr. (Cambridge, Mass., 1981), 142–62. For a discussion of how some engineers found an alternative to their traditional technological roles in the conservation movement and how they attempted to use this new movement to guide public policy, see Edwin T. Layton Jr., *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession* (Cleveland, 1971), 63–65.

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mechanical means in the nineteenth and early twentieth centuries. Subsequent technological advances, they argued, reduced the pressure placed upon forests, helping to reverse the earlier devastation. The environmental effects of other technological developments escaped their attention, however, until the authors moved their narrative past World War II, when they addressed such issues as DDT, automotive pollution, groundwater depletion, Love Canal, and the rising political tide of environmentalism.[27]

Rather than pigeonholing environmental discussions in his 1995 history of American technology, *The Machine in America,* Carroll Pursell wove a sophisticated treatment of the interface of technology and the environment throughout the book. He explained, for example, how the geography of the Atlantic coastal region shaped the transfer and modification of European technologies during the colonial period and how North America's landscapes and natural resources influenced the contours of industrialization and agriculture in the United States. He also discussed the impact of automobility on the nation's cities and countryside and the challenges of the post-1960s environmental movement. More than any other survey published to date, Pursell's treatment stands as a model for other historians of technology concerned with addressing environmental variables.[28]

In contrast, Ruth Schwartz Cowan's 1997 textbook paid little attention to the effects of technology on the environment, dismissing the ecological impact of nineteenth-century industry with the comment that "environmental protection [was] barely recognized as necessary." She did mention the air pollution generated by automobiles in a section entitled "The Unexpected Consequences of Automobility" but took no account of other types of pollution or environmental damages.[29] Merritt Roe Smith and Gregory Clancey charted a different course in their recent anthology of documents and essays on the history of American technology by prominently integrating environmental perspectives in three of their thirteen chapters. They also selected brief treatments of environmental considerations for several other chapters, although they chose not to highlight the environmental theme within their own introductory remarks.[30]

27. Alan I Marcus and Howard P. Segal, *Technology in America: A Brief History* (San Diego, 1989), 194–202, 346–48; Gary Cross and Rick Szostak, *Technology and American Society: A History* (Englewood Cliffs, N.J., 1995).

28. Carroll Pursell, *The Machine in America: A Social History of Technology* (Baltimore, 1995). For a mirror image of Pursell's textbook, see John Opie, *Nature's Nation: An Environmental History of the United States* (Fort Worth, Tex., 1998), which makes the most thorough effort to date to incorporate the literature and insights of the history of technology into a sweeping textbook of American environmental history.

29. Ruth Schwartz Cowan, *A Social History of American Technology* (New York, 1997), 131, 234–43.

30. Merritt Roe Smith and Gregory Clancey, eds., *Major Problems in the History of American Technology* (Boston, 1998).

Cities and the Environment

Historians have paid more attention to the interplay of technology and the environment in urban settings than in most other contexts. As built environments, cities consist of anthropogenically created structures, including buildings of all sorts, streets, roads, pavements, and above- and belowground infrastructures. A large literature is devoted to these urban technologies, whose environmental effects are, however, typically neglected. Nelson M. Blake's pioneering work, *Water for the Cities,* was an exception. It dealt with the technology of water supply and its relationship to water pollution and public health, although it ignored the ecological impacts of dams and large reservoirs. Carl W. Condit's impressive two-volume history of Chicago's urban technologies is another important work that examines city development, technology, and the environment. Although focused on the growth of the city's built environment, the study paid considerable attention to Chicago's geographical setting, the pollution caused by development, and the construction of waterways and municipal parks.[31]

The role of technology in city building, with coincidental attention to some environmental effects, received a major stimulus with the publication of the American Public Works Association's bicentennial tribute, *History of Public Works in the United States, 1776–1976.* Editors Ellis L. Armstrong, Michael C. Robinson, and Suellen M. Hoy included chapters on such environmentally related subjects as sewers, solid wastes, and water supply.[32] The Public Works Historical Society followed this volume with a series of complementary essays that provided case studies on urban water supply, sewage treatment, sanitation, and solid waste disposal.[33] The focus of these histo-

31. Nelson M. Blake, *Water for the Cities: A History of the Urban Water Supply Problem in the United States* (Syracuse, N.Y., 1956); and Carl W. Condit, *Chicago, 1910–70: Building, Planning, and Urban Technology,* 2 vols. (Chicago, 1973, 1974). For reasons not entirely clear, when Condit subsequently studied the port of New York, he paid considerably less attention to environmental variables. See Carl W. Condit, *The Port of New York,* vol. 1, *A History of the Rail and Terminal System from the Beginnings to Pennsylvania Station,* and vol. 2, *A History of the Rail and Terminal System from the Grand Central Electrification to the Present* (Chicago, 1980, 1981).

32. Ellis L. Armstrong, Michael C. Robinson, and Suellen M. Hoy, eds., *History of Public Works in the United States, 1776–1976* (Chicago, 1976). For a parallel study of Canadian cities that benefited from subsequent scholarship on these topics, see Norman R. Ball, ed., *Building Canada: A History of Public Works* (Toronto, 1988).

33. See, for example, James C. O'Connell, *Chicago's Quest for Pure Water* (Chicago, 1976); Edward C. Carter II, *Benjamin Henry Latrobe and Public Works: Professionalism, Private Interest, and Public Policy in the Age of Jefferson* (Chicago, 1976); Martin V. Melosi, *Pragmatic Environmentalist: Sanitary Engineer George E. Waring, Jr.* (Chicago, 1977); Larry D. Lankton, *The "Practicable" Engineer: John B. Jervis and the Old Croton Aqueduct* (Chicago, 1977); Joel A. Tarr, *Transportation Innovation and Changing Spatial Patterns in Pittsburgh, 1850–1934* (Chicago, 1978); Todd A. Shallat, *Fresno's Water Rivalry: Com-*

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ries, however, was on city building, not urban ecology. Aside from the public health effects of wastewater and solid waste disposal, no explicit attention was paid to the environmental impact of municipal technologies, even when those impacts were substantial, as with the construction of highways and mass transportation systems.

Much of the systematic work on the environmental consequences of urban technology focused on wastewater systems and the waterways that served as sewage sinks. Although Blake and Condit acknowledged this concern in their books, it was not until the late 1970s and early 1980s that historians turned their full attention to the subject. An NSF grant for a "retrospective technology assessment" of wastewater technology proved especially important in this regard, by sponsoring research on the development of sewerage technology and its social and environmental effects. The NSF report itself emphasized how city officials and engineers often made technology decisions to improve local sanitary conditions with little concern for downstream impacts. It also explored the influence of urban technology design choices on both public health and nuisance conditions, as well as how they stimulated such institutional developments as the special authority.[34]

Martin V. Melosi has been a leading proponent of assessing the interplay of municipal technologies and the environment. In two influential volumes published in the early 1980s, *Pollution and Reform in American Cities, 1870–1930* and *Garbage in the Cities: Refuse, Reform, and the Environment,* he dealt specifically with the historical role of technology in despoiling urban environments. The first was a pioneering edited work that addressed water supply, solid wastes, sewerage systems, noise and smoke pollution, and the general degradation of towns and cities caused by industrialization. His subsequent monograph traced the efforts of municipalities to cope with their ever-increasing solid waste problems. In so doing, Melosi touched upon concerns central to both the history of technology and environmental history. For example, he addressed the development of alternative collection methods and disposal technologies (such as the incinerator and the sanitary landfill), the environmental impact of these technologies,

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petition for a Scarce Resource, 1887–1970 (Chicago, 1979); Louis P. Cain, *The Search for an Optimum Sanitation Jurisdiction: The Metropolitan Sanitary District of Greater Chicago* (Chicago, 1980); Jeffrey K. Stine, *Nelson P. Lewis and the City Efficient: The Municipal Engineer in City Planning during the Progressive Era* (Chicago, 1981); and Carol Hoffecker, *Water and Sewage Works in Wilmington, Delaware, 1810–1910* (Chicago, 1981).

34. Joel A. Tarr et al., *A Retrospective Assessment of Wastewater Technology in the United States, 1800–1972: A Report to the National Science Foundation* (Pittsburgh, 1978). This document was later summarized in Tarr et al., "Water and Wastes" (n. 16 above). See also Joel A. Tarr, ed., *Retrospective Technology Assessment, 1976* (San Francisco, 1977).

and the formation of a special branch of engineering—sanitary engineering—to deal with waste disposal.[35]

The late 1970s and 1980s witnessed an outpouring of urban technology studies, many concerned with individual cities and specific infrastructures. Louis Cain, for instance, detailed the historical development and interaction of Chicago's water supply and wastewater systems, mixing economic analysis with discussions of technology. Eugene Moehring also paid considerable attention to the development of water supply and wastewater technologies in his history of nineteenth-century public works in New York City. Other studies of the city building process followed in rapid succession, each of which dealt to some degree with environmental questions associated with water supply, sewerage systems, parks, and landscapes. Among these were Harold L. Platt on Houston; Christine Meisner Rosen on the rebuilding of Baltimore, Boston, and Chicago in the aftermath of devastating fires; and Ann Durkin Keating on Chicago's early suburbs. Stanley K. Schultz's study of late-nineteenth- and early-twentieth-century city planning built upon these works, dealing explicitly with the relationship of municipal engineering to public health and the environment, including evaluations of infrastructure construction, sanitation, and park development.[36]

The history of air pollution is another urban environmental problem that has received significant attention. The earliest studies tended to focus more on policy than on technology.[37] London's infamous air pollution

35. Martin V. Melosi, ed., *Pollution and Reform in American Cities, 1870–1930* (Austin, Tex., 1980); and Martin V. Melosi, *Garbage in the Cities: Refuse, Reform, and the Environment* (College Station, Tex., 1981). For his other major work bearing upon the intersection of technology and the environment, see Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia, 1985). An expanded treatment of urban noise pollution can be found in Raymond W. Smilor, "Confronting the Industrial Environment: The Noise Problem in America, 1893–1932" (Ph.D. diss., University of Texas, 1978).

36. Louis Cain, *Sanitation Strategy for a Lakefront Metropolis: The Case of Chicago* (DeKalb, Ill., 1978); Eugene Moehring, *Public Works and the Patterns of Urban Real Estate Growth in Manhattan, 1835–1894* (New York, 1981); Harold L. Platt, *City Building in the New South: The Growth of Public Services in Houston, Texas, 1830–1910* (Philadelphia, 1983); Christine Meisner Rosen, *The Limits of Power: Great Fires and the Process of City Growth in America* (New York, 1986); Ann Durkin Keating, *Building Chicago: Suburban Developers and the Creation of a Divided Metropolis* (Chicago, 1988); and Stanley K. Schultz, *Constructing Urban Culture: American Cities and City Planning, 1899–1920* (New York, 1989). Also useful are Warner (n. 2 above); Charles H. Weidner, *Water for a City: A History of New York City's Problem from the Beginning to the Delaware River System* (New Brunswick, N.J., 1974); Fern L. Nesson, *Great Waters: A History of Boston's Water Supply* (Hanover, N.H., 1983); and Gail Cooper, *Air-conditioning America: Engineers and the Controlled Environment, 1900–1960* (Baltimore, 1998).

37. See, for example, Oscar H. Allison, "Raymond R. Tucker: The Smoke Elimination Years, 1934–1950" (Ph.D. diss., St. Louis University, 1978); and R. Dale Grinder, "The Battle for Clean Air: The Smoke Problem in Post–Civil War America," in Melosi, *Pollution and*

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and its associated fuel crises, however, were made to order for historians of technology. Two of the best articles on this subject appeared in *Technology and Culture*: William H. Te Brake examined the period from 1250 to 1650 and concluded that the "present environmental crisis [was] the result of centuries of struggle by Western man to achieve dominance over his natural world." Te Brake maintained that environmental problems in the Middle Ages differed mainly in "scale and degree" from today's problems. Carlos Flick followed with a study of London's nineteenth-century smoke abatement movement. He found that although technologies were available to reduce smoke production, enforcing smoke control laws was nearly impossible, given the multitude of domestic coal burners.[38] Joel Tarr and Bill Lamperes developed these themes for the United States in a case study of Pittsburgh's smoke control policy during the 1940s, relating smoke control efforts to changing technology and fuel use, as well as to strengthened smoke control laws. Tarr then turned to the problem of railroad smoke in cities, examining the various strategies used to curtail it, including behavioral approaches and mandatory fuel and technology shifts.[39]

The automobile is the transportation technology most associated with environmental degradation. Historians of technology, however, did not take up the challenge of examining the automobile's environmental impacts, or the efforts to curb those impacts, until the mid-1990s.[40] Two

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Reform in American Cities. For a discussion of the smoke pollution inflicted upon Pennsylvania towns by charcoal making and the iron industry, see Arthur Cecil Bining, *Pennsylvania Iron Manufacture in the Eighteenth Century* (Harrisburg, Pa., 1973), 59–64. For the smoke nuisance produced by the heaters and blowers used to protect southern California's citrus crops from frost damage, see Alan M. Paterson, "Oranges, Soot, and Science: The Development of Frost Protection in California," *Technology and Culture* 16 (July 1975): 360–76.

38. Te Brake (n. 16 above); and Flick (n. 16 above). For subsequent studies of smoke control in Great Britain, see Eric Ashby and Mary Anderson, *The Politics of Clean Air* (Oxford, 1981); Peter Brimblecomb, *The Big Smoke: A History of Air Pollution in London since Medieval Times* (London, 1987); and Newell (n. 1 above).

39. See Joel A. Tarr and Bill Lamperes, "Changing Fuel Use Behavior and Energy Transitions: The Pittsburgh Smoke Control Movement, 1940–1950, A Case Study in Historical Analogy," *Journal of Social History* 14 (1981): 561–88; and Joel A. Tarr and Kenneth Koons, "Railroad Smoke Control: A Case Study in the Regulation of a Mobile Pollution Source," in *Energy and Transport: Historical Perspectives in Policy Issues*, ed. George H. Daniels and Mark H. Rose (Beverly Hills, Calif., 1982), 71–92. Also useful are Joel A. Tarr and Carl Zimring, "The Struggle for Smoke Control in St. Louis: Achievement and Emulation," in *Common Fields: An Environmental History of St. Louis*, ed. Andrew Hurley (Saint Louis, 1997), 199–220; and David Stradling, "Civilized Air: Coal, Smoke, and Environmentalism in America, 1880–1920" (Ph.D. diss., University of Wisconsin, Madison, 1996).

40. Scott Hamilton Dewey, "'Don't Breathe the Air': Air Pollution and the Evolution of Environmental Policy and Politics in the U.S., 1945–1979" (Ph.D. diss., Rice University, 1997).

southern California law professors, James E. Krier and Edmund Ursin, had earlier published the first systematic historical consideration of automobile-generated air pollution and society's attempts to regulate it. Their book dealt with the emergence of southern California's air pollution problem, the identification of its causes, and the resulting policy responses.[41] General histories of the automobile, such as those of James J. Flink, virtually ignored the mounting damage to air quality before the establishment of environmental regulations. The ecological consequences of constructing vast networks of paved streets and roads and extensive state and national highway systems to accommodate the automobile have also attracted only modest attention from historians.[42]

In his masterful 1991 study, *Nature's Metropolis,* William Cronon demonstrated another way that historians can utilize the theme of technology and the environment to understand urban development, particularly the interconnections between city and country. Cronon traced the flow of commodities such as grain, lumber, and beef from the hinterland into Chicago for processing and thence on to other markets during the second half of the nineteenth century. Technology was essential to this exploitation of nature through the harvesting and extraction of resources, the transporting of the raw materials to processing and packaging plants, and the shipping of the commodities to consumers within Chicago and beyond. Railroads, refrigerated boxcars, industrial-scale slaughterhouses, sawmills, reapers, and grain elevators combined to make Chicago the "Gateway to the West" and the linchpin coupling the bounty of nature and the markets of the East. Cronon argued that in the process of reaping nature's products, however, people transformed "first nature" into "second nature," mastered by technology and subjected to the whims of the consumer market. Although *Nature's Metropolis* paid little attention to the urban environment

41. James E. Krier and Edmund Ursin, *Pollution and Policy: A Case Essay on California and Federal Experience with Motor Vehicle Air Pollution, 1940–1975* (Berkeley, 1977). See also Frank P. Grad et al., *The Automobile and the Regulation of Its Impact on the Environment* (Norman, Okla., 1975); Marvin Brienes, "The Fight against Smog in Los Angeles, 1943–1957" (Ph.D. diss., University of California, Davis, 1975); and Ralph Gakenheimer, ed., *The Automobile and the Environment: An International Perspective* (Cambridge, Mass., 1978).

42. James J. Flink, *The Automobile Age* (Cambridge, Mass., 1988), 386–88. See also Mark S. Foster, *From Streetcar to Superhighway: American City Planners and Urban Transportation, 1900–1940* (Philadelphia, 1981); Scott L. Bottles, *Los Angeles and the Automobile: The Making of the Modern City* (Berkeley, 1987); Bruce E. Seely, *Building the American Highway System: Engineers as Policy Makers* (Philadelphia, 1987); and Clay McShane, *Down the Asphalt Path: The Automobile and the American City* (New York, 1994). Several authors have examined the issue of lead additives to gasoline and their health effects on workers. This research has been summarized in Mark Aldrich, *Safety First: Technology, Labor, and Business in the Building of American Work Safety, 1870–1939* (Baltimore, 1997).

itself, more such studies that outline the relationships between city and country during various periods and highlight the integral role of technology in these linkages would clearly give us greater insights into the overall interplay of technology and the natural environment.[43]

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Public Health and Occupational Health and Safety

Because public health is heavily influenced by interactions between technology and the environment, public health historians have long discussed the importance of clean water and sewers, although they have paid little attention to technological details.[44] Merril Eisenbud, a physician and public health administrator specializing in environmental health, examined the links between technology, the environment, and public health over time. He divided his 1978 study *Environment, Technology, and Health: Human Ecology in Historical Perspective* into two parts, the first addressing the preindustrial period and the impact of industrialism, the second dealing with contemporary environmental concerns, such as cancer and the environment, organic chemicals, metals, sulfur oxides and fossil fuel combustion particulates, air pollution, and nuclear power. He provided historical background for each of these concerns, arguing that the environmental movement itself had distorted history by neglecting technology's role in improving, as well as damaging, the conditions of human life. The societal problem, as he saw it, was whether the "deleterious effects" of technology could be held to an "acceptable level," a goal he thought was achievable through the application of careful technology assessment.[45]

While not focusing on technology to the extent that Eisenbud did, other public health historians of the 1970s and 1980s studied the impacts of technology on public health and the urban environment. Scholars such as Barbara Rosenkrantz, John Duffy, Judith Walzer Leavitt, and Stuart Galishoof published important books on the public health problems caused by rapid urbanization and industrialization. In addition to chronicling the expansion of state authority, the authors considered such technologically related variables as water pollution, water filtration, construction of sewerage systems, solid waste disposal, and street cleaning. Nevertheless, these public health historians typically took a narrow view of technology and the

43. William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York, 1991).

44. For an early expression of interest in the historical connections between technology and public health, see S. Colum Gilfillan's letter to the editor, "The Inventive Lag in Classical Mediterranean Society," *Technology and Culture* 3 (1962): 85–87, which discusses the impact of lead poisoning on the Roman aristocracy.

45. Merril Eisenbud, *Environment, Technology, and Health: Human Ecology in Historical Perspective* (New York, 1978), 3, 8–12.

environment, treating technology as a given and the environment only as it related to public health.[46]

Several recent books have dealt with technology and cleanliness, both in the city at large and in the home, and have related them to public health. This is significant, as public health concerns proved crucial in enlarging the popularity of the post–World War II environmental movement. Suellen Hoy employed a broad canvas to trace the American pursuit of cleanliness, dealing with the interactions between the cultural and social forces that affected human behavior and the technologies that permitted altered lifestyles. Maureen Ogle's study of nineteenth-century household plumbing demonstrated how town and city dwellers devised ingenious water supply and wastewater disposal technologies in the absence of sewers or piped-in water. A substantial number of these works addressed gender-related variables, such as the demands placed on women by housework, poor urban sanitation, and limited municipal services. Whether technology added to or reduced housewives' burdens is an area of some contention, but few question that technologies relating to water supply and human waste disposal improved the quality of daily life for all who had them. The picture becomes more complicated for domestic technologies; as Ruth Schwartz Cowan has argued, many supposedly labor-saving devices, such as the vacuum cleaner and washing machine, actually increased housework.[47]

Worker health and safety have been closely related to public health, both in the definition, recognition, and control of occupational disease and in the occurrence and prevention of workers' accidents. Arthur McEvoy argued that "[e]conomically, the damage that industrial accidents and disease do to workers' bodies is very much like the damage that industry does to the natural environment: both pollution and work injuries are social costs, so

46. Barbara Gutmann Rosenkrantz, *Public Health and the State: Changing Views in Massachusetts, 1842–1936* (Cambridge, Mass., 1972); John Duffy, *A History of Public Health in New York City, 1625–1866* (New York, 1968), and *A History of Public Health in New York City, 1866–1966* (New York, 1974); Judith Walzer Leavitt, *The Healthiest City: Milwaukee and the Politics of Health Reform* (Princeton, N.J., 1982); and Stuart Galishoof, *Newark: The Nation's Unhealthiest City, 1832–1895* (New Brunswick, N.J., 1988).

47. Suellen Hoy, *Chasing Dirt: The American Pursuit of Cleanliness* (New York, 1995); Maureen Ogle, *All the Modern Conveniences: American Household Plumbing, 1840–1890* (Baltimore, 1996); and Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York, 1983). See also Susan Strasser, *Never Done: A History of American Housework* (New York, 1982); S. J. Kleinberg, *The Shadow of the Mills: Working-Class Families in Pittsburgh, 1870–1907* (Pittsburgh, 1989); Richard L. Bushman, *The Refinement of America: Persons, Houses, Cities* (New York, 1992); Carolyn M. Goldstein, "Mediating Consumption: Home Economics and American Consumers, 1900–1940" (Ph.D. diss., University of Delaware, 1994); and Arwen Palmer Mohun, *Power Laundries: Gender, Technology, and Work in Great Britain and the United States, 1880–1940* (forthcoming).

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broadly diffused over large numbers of politically inarticulate victims that employers are rarely called to account for them."[48] Although early works in this area date from the 1940s, it was not until the mid-1970s that public health and labor historians began seriously studying workers' occupational health.[49] Many of these later works dealt directly with the natural environment—with hard-rock and coal mining, for example. Among the most in-depth of these histories are William Graebner's examination of the political economy of Progressive Era coal-mining safety, Mark Wyman's study of the industrialization of hard-rock mining in the American West, Alan Derickson's critique of the hazards faced by western miners from 1891 to 1925, and Martin Cherniack's chronicle of the Hawk's Nest industrial disaster.[50]

In the late 1980s, David Rosner and Gerald Markowitz edited a book on industrial hygiene that covered many of the same types of extractive industries and followed it with a detailed study of the 1930s silicosis crisis. Observing that the "very machines and technical innovations that were at the root of America's industrial might" produced the deadly silicosis disease, they challenged the belief that technological improvement and industrial growth would automatically improve workers' lives.[51] The books on mining and miners cited in the preceding paragraph all made similar arguments. Although none were written by historians of technology, all took technology and technological change as important factors in the deterioration of workplace conditions.[52]

48. McEvoy, "Working Environments" (n. 13 above), p. S160. See also Richard White, "Are You an Environmentalist or Do You Work for a Living? Work and Nature," in *Uncommon Ground: Toward Reinventing Nature,* ed. William Cronon (New York, 1995), 171–85.

49. See, for example, Hubert Skidmore, *Hawk's Nest* (New York, 1941); George Rosen, *The History of Miners' Disease* (New York, 1943); and Louis Teleky, *History of Factory and Mine Hygiene* (New York, 1948).

50. William Graebner, *Coal-Mining Safety in the Progressive Period: The Political Economy of Reform* (Lexington, Ky., 1976); Mark Wyman, *Hard Rock Epic: Western Miners and the Industrial Revolution, 1860–1910* (Berkeley, 1979); Alan Derickson, *Workers' Health, Workers' Democracy: The Western Miners' Struggle, 1891–1925* (Ithaca, N.Y., 1988); and Martin Cherniack, *The Hawk's Nest Incident: America's Worst Industrial Disaster* (New Haven, Conn., 1986). See also Jacqueline Karnell Corn, *Response to Occupational Health Hazards: A Historical Perspective* (New York, 1992); and Mark Aldrich, "Preventing 'the Needless Peril of the Coal Mine': The Bureau of Mines and the Campaign against Coal Mine Explosions, 1910–1940," *Technology and Culture* 36 (1995): 483–518.

51. David Rosner and Gerald Markowitz, *Deadly Dust: Silicosis and the Politics of Occupational Disease in Twentieth-Century America* (Princeton, N.J., 1991), 8–9. Their earlier book was David Rosner and Gerald Markowitz, eds., *Dying for Work: Workers' Safety and Health in Twentieth-Century America* (Bloomington, Ind., 1987).

52. For a corroborating account of a related industry, see Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910–1935* (Chapel Hill, N.C., 1997). Also useful are Barton C. Hacker, *The Dragon's Tail: Radiation Safety in the Manhattan Project, 1942–1946* (Berkeley, 1987), and *Elements of Controversy: The Atomic Energy*

These specialized studies provided the basis for two recent works of synthesis and research: Christopher C. Sellers's historical account of industrial hygiene and Mark Aldrich's evaluation of workplace accidents and safety.[53] Sellers, a medical doctor with a Ph.D. in environmental history, combines a sophisticated assessment of the medical aspects of industrial hygiene with the perspective of environmental history. He provides deep insight into the explanations suggested by researchers and physicians concerning the effects of various industrial occupations on workers' health. Of necessity, technology plays a major role in his book, although it is always subordinate to the issues of workers' health and the evolution of health analysis methodologies. He emphasizes the development of industrial hygiene, its professionalization, and its broadening out from a disciplinary concern with workplace health into a science of environmental health.

While Sellers focused on occupational health, Aldrich, an economic historian, examined industrial safety in manufacturing, mining, and the railroads. Aldrich pays considerable attention to the technologies involved and to changes in their operation and form. He concludes that the increased danger of work during the late nineteenth and early twentieth centuries resulted from an American system that focused on high productivity without proper attention to the potential effects of new technologies on worker safety. Over time, says Aldrich, workplace safety improved as workers began moving from more dangerous sectors of the economy, such as mining and lumbering, to less dangerous sectors, such as manufacturing and white-collar occupations. These long-term gains were further enhanced by economic development, an expanded safety movement, and the institutionalization of safety concerns within the management structure of large firms.[54]

Industry and Manufacturing

Historians of technology have on the whole neglected not only worker safety but also the environmental consequences of industry and manufacturing. There are exceptions, however. Joseph A. Pratt's 1980 study of the

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Commission and Radiation Safety in Nuclear Weapons Testing, 1947–1974 (Berkeley, 1994).

53. Christopher C. Sellers, *Hazards of the Job: From Industrial Disease to Environmental Health Science* (Chapel Hill, N.C., 1997); and Aldrich, *Safety First* (n. 42 above).

54. Aldrich, *Safety First.* The concept of risk, as it involves the nexus of technology and the environment, is explored in Mary Douglas and Aaron Wildavsky, *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers* (Berkeley, 1982); and Aaron Wildavsky, *But Is It True? A Citizen's Guide to Environmental Health and Safety Issues* (Cambridge, Mass., 1995). Also useful is Allan Mazur, *A Hazardous Inquiry: The "Rashomon" Effect at Love Canal* (Cambridge, Mass., 1998).

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Texas Gulf Coast petroleum refining area, for example, included a chapter on past pollution in which he treated pollution as a major component of industry operations rather than an occasional and incidental happening. More recently, Andrew Hurley traced problems with oil pollution in New York harbor back to the late nineteenth century, and John T. Cumbler detailed the damaging effects of the medals industry on the Connecticut River.[55] The most far-reaching treatment of the ecological impact of industrial processes is Robert B. Gordon and Patrick M. Malone's 1994 study, *The Texture of Industry.* Their book was deeply informed by the insights of industrial archeology, as manifested in the abundant details it provides on the evolution of artifacts and material culture. In addition to the book's evaluations of physical remains, what sets it apart from other industrial histories is its attention to the environmental effects of technologies and techniques such as iron and steelmaking, subsurface and surface mining of fuel and metals, energy production, and smelting and refining, often illustrated with striking photographs.[56]

Theodore Steinberg's history of waterpowered mills along the Merrimack River examined the environmental transformation of this New England watershed and how industrialists used the legal system to control the region's waters. William McGucken and Terence Kehoe have also written environmental histories focused on industry: McGucken on the ecological impact of detergents, and Kehoe on efforts to clean up the Great Lakes.[57] Works such as these are the exception, however, especially in regard to heavy industry. Histories of the chemical industry, for instance, barely touch on environmental effects, even though, as Ralph Landau and Nathan Rosenberg note, the "industry everywhere has been one of the very first to encounter environmental restraints and challenges to its activities."[58] Most

55. Joseph A. Pratt, *The Growth of a Refining Region* (Greenwich, Conn., 1980); Hurley, "Creating Ecological Wastelands" (n. 22 above), 340–64; and John T. Cumbler, "Whatever Happened to Industrial Waste? Reform, Compromise, and Science in Nineteenth Century Southern New England," *Journal of Social History* 29 (fall 1995): 149–71. See also H. Wayne Morgan, ed., *Industrial America: The Environment and Social Problems, 1865–1920* (Chicago, 1974); and Joseph A. Pratt, "Letting the Grandchildren Do: Environmental Planning during the Ascent of Oil as a Major Energy Source," *Public Historian* 2 (summer 1980): 28–61.

56. Robert B. Gordon and Patrick M. Malone, *The Texture of Industry: An Archaeological View of the Industrialization of North America* (New York, 1994).

57. Theodore Steinberg, *Nature Incorporated: Industrialization and the Waters of New England* (New York, 1991); William McGucken, *Biodegradable: Detergents and the Environment* (College Station, Tex., 1991); and Terence Kehoe, *Cleaning Up the Great Lakes: From Cooperation to Confrontation* (DeKalb, Ill., 1997). See also Theodore Steinberg, "An Ecological Perspective on the Origins of Industrialization," *Environmental Review* 10 (winter 1986): 261–76.

58. Ralph Landau and Nathan Rosenberg, "Successful Commercialization in the Chemical Process Industries," in *Technology and the Wealth of Nations,* ed. Nathan Rosenberg, Ralph Landau, and David C. Mowery (Stanford, 1992), 74–119.

histories of chemical firms ignore the environmental havoc wrought by the chemical industry prior to the 1960s, when federal regulatory oversight increased. This omission disregards the industry's starring role in polluting the nation's air, land, and water since the late nineteenth century. Many chemical firms consistently violated existing state antipollution laws and became the target of multiple nuisance lawsuits.[59]

The iron and steel industry is another major enterprise whose serious environmental effects over time have been neglected. Because of the extensive natural resource inputs required to make iron and steel, it would seem next to impossible for studies of this industry to ignore its relationship to the environment. Yet, most historians of the iron and steel industry gloss over or totally ignore such questions. Paul F. Paskoff's fine history of the Pennsylvania iron industry, for instance, in discussing the technology of charcoal iron and the amount of timber required to maintain charcoal iron plantations, pays only limited attention to the industry's impact on forested lands and regional air quality.[60] For a thorough assessment of the punishment inflicted upon forests by charcoal iron making, one has to turn to geographer Michael Williams's magnum opus, *Americans and Their Forests.*[61]

The picture is similar for iron ore mining and the steel industry as a whole. Like Joseph Pratt's book on oil refining, Robert V. Bartlett's examination of the discharge of iron tailings into Lake Superior opened a window on the environmental impact of technology, yet it failed to attract a following.[62] The studies of the iron and steel industry by historians of technology,

59. Sheldon Hochheiser, *Rohm and Haas: History of a Chemical Company* (Philadelphia, 1986); David A. Hounshell and John K. Smith Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (New York, 1988); Andrew J. Butrica, *Out of Thin Air: A History of Air Products and Chemicals, Inc., 1940–1990* (New York, 1990); David Dyer and David B. Sicilia, *Labors of a Modern Hercules: Evolution of a Chemical Company* (Boston, 1990); and Fred Aftalion, *A History of the International Chemical Industry,* trans. Otto Theodor Benfey (Philadelphia, 1991). For a study of the environmental impact of the chemical industry, see Colton, "Creating a Toxic Landscape" (n. 21 above).

60. Paul F. Paskoff, *Industrial Evolution: Organization, Structure, and Growth of the Pennsylvania Iron Industry, 1750–1860* (Baltimore, 1983). Bining, *Pennsylvania Iron Manufacture* (n. 37 above), briefly mentions the timber consumed and the air pollution created by charcoal furnaces. For an economic analysis of the industry that examines wood as a factor input, while ignoring the environmental impact of deforestation, see Peter Temin, *Iron and Steel in Nineteenth-Century America* (Cambridge, Mass., 1964). Also useful are Tarr, "Searching for a 'Sink'" (n. 21 above); and Brooke Hindle, ed., *Material Culture of the Wooden Age* (Tarrytown, N.Y., 1981). For the impact of railroads on forests, see Sherry H. Olson, *The Depletion Myth: A History of Railroad Use of Timber* (Cambridge, Mass., 1971).

61. Michael Williams, *Americans and Their Forests: A Historical Geography* (New York, 1989). The nineteenth-century wood chemical industry also had a devastating impact on forest resources, but it has yet to find its historian.

62. Robert V. Bartlett, *The Reserve Mining Controversy: Science, Technology, and Environmental Quality* (Bloomington, Ind., 1980). For the environmental litigation that

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business historians, economists, and geographers explore many aspects of the enterprise's evolution, its relationship to railroad development, the construction and culture of cities, and the buildup of the army and navy, but they largely ignore environmental variables. John N. Ingham's excellent monograph on Pittsburgh's independent iron and steel mills from 1820 to 1920, for instance, does not even mention Pittsburgh's infamous smoke problem. Similarly, Thomas J. Misa's Dexter Prize-winning industrial history, *A Nation of Steel,* completely sidesteps the steel industry's major impacts on air and water quality and land use in such manufacturing centers as Birmingham, Alabama; Gary, Indiana; and Pittsburgh.[63]

Environmental, labor, and social historians who have studied the steel industry and its associated mill towns have been more sensitive to ecological variables. S. J. Kleinberg's penetrating analysis of Pittsburgh's working-class families deals with the problem of the mills' smoke and fumes and their impact on workers and their neighborhoods. Andrew Hurley's pioneering monograph on Gary, distinguished for its clear treatment of the steel industry's technological systems, examines the interconnections between class, race, and environmental quality in the context of the U.S. Steel Corporation's huge industrial complex. And Joel Tarr's recent article on pollution from the coking industry sketches out how this steel-related industry polluted both water and air in major industrial areas. One important route to tracing the environmental effects of manufacturing is through the use of nuisance cases. Here Christine Meisner Rosen's several articles have been particularly helpful in defining those nuisances and documenting how the courts reacted to the associated litigation.[64]

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followed, see Thomas F. Bastow, *"This Vast Pollution . . .": United States of America v. Reserve Mining Company* (Washington, D.C., 1986).

63. John N. Ingham, *Making Iron and Steel: Independent Mills in Pittsburgh, 1820–1920* (Columbus, Ohio, 1991); and Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865–1925* (Baltimore, 1995). Ingham's dust jacket features a striking image of darkened clouds billowing from mill smokestacks. The few works that have addressed the history of iron and steel making in the American West have focused on the economic, industrial, and technological components, rather than on the environmental. See, for example, H. Lee Samehorn, *Pioneer Steelmaker in the West: The Colorado Fuel and Iron Company, 1872–1903* (Boulder, Colo., 1976), and *Mill and Mine: The CF&I in the Twentieth Century* (Lincoln, Nebr., 1992).

64. Kleinberg (n. 47 above); Andrew Hurley, *Environmental Inequalities: Class, Race, and Industrial Pollution in Gary, Indiana, 1945–1980* (Chapel Hill, N.C., 1995); Tarr, "Searching for a 'Sink'"; Christine Meisner Rosen, "Differing Perceptions of the Value of Pollution Abatement across Time and Place: Balancing Doctrine in Pollution Nuisance Law, 1804–1906," *Law and History Review* 11 (fall 1993): 303–81, and "Noisome, Noxious, and Offensive Vapors, Fumes, and Stenches in American Towns and Cities, 1840–1865," *Historical Geography* 25 (1997): 49–82. See also Martin V. Melosi, "Hazardous Waste and Environmental Liability: An Historical Perspective," *Houston Law Review* 25 (1988): 741–80.

The interrelationships between industrialization, the environment, and public policy are also revealed through the examination of technology's long-term impact on the land. Over the last quarter-century, industries have vacated numerous urban sites, leaving the communities burdened with large tracts of abandoned land. Many such settings are contaminated with toxic wastes, imposing high costs for cleanup and reuse. Sometimes, issues of environmental justice are involved. Craig Colten, Hugh Gorman, and Andrew Hurley have begun exploring these questions of industrial land use and have published valuable case studies of different sites, but much more needs to be done.[65]

Natural Resources

Next to the study of urban settings, one of the oldest areas in which technological and environmental history have overlapped is the history of water resources development. Here the engineering efforts to manipulate and control nature have been blatant and often monumental, the ecological effects inescapable and often profound. The construction of dams, the destruction of rivers, the large-scale transport of water, the mining of ancient groundwater reserves, the provision of navigation structures, the armoring of river banks and shorelines, the channelization of streams, the installation of vast irrigation systems and hydroelectric power facilities, the provision of fish ladders, the mounding of levees, the dredging of harbors and waterways, and the reclamation of wetlands are all elements of this history. Moving mass quantities of water around—whether for water supply, irrigation, transportation, or hydroelectric power generation—necessarily requires significant technological works and invariably causes substantial environmental disruptions. Although these complex stories of transformation have attracted the sustained attention of technological and environ-

65. See Craig E. Colten, "Industrial Middens in Illinois: The Search for Historical Hazardous Wastes, 1870–1980," *IA: The Journal of the Society for Industrial Archeology* 14, no. 2 (1988): 51–61, "Historical Hazards: The Geography of Relict Industrial Wastes," *Professional Geographer* 42 (May 1990): 143–56, and "Chicago's Waste Lands: Refuse Disposal and Urban Growth, 1840–1990," *Journal of Historical Geography* 20 (April 1994): 124–42; Craig E. Colten and Peter N. Skinner, *The Road to Love Canal: Managing Industrial Waste before EPA* (Austin, Tex., 1996); Gorman (n. 1 above); and Andrew Hurley, "Fiasco at Wagner Electric: Environmental Justice and Urban Geography in St. Louis," *Environmental History* 2 (1997): 460–81. Useful methodological suggestions are provided in Shelley Bookspan, "Potentially Responsible Party Searches: Finding the Cause of Urban Grime," *Public Historian* 13 (spring 1991): 25–34. For the environmental justice movement, see Robert D. Bullard, *Dumping in Dixie: Race, Class, and Environmental Quality* (Boulder, Colo., 1990); Robert D. Bullard, ed., *Unequal Protection: Environmental Justice and Communities of Color* (San Francisco, 1994); Hurley, *Environmental Inequalities*; and Christopher H. Foreman Jr., *The Promise and Peril of Environmental Justice* (Washington, D.C., 1998).

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mental historians, rarely have scholars given equal consideration to technology and the environment as agents of change. More typically, one element is presented as backdrop for the other. Robert M. Morgan's *Water and the Land,* for example, covers numerous irrigation technologies but largely ignores the ecological implications of such engineering works. Along those same lines, two other recent works of technological history—Todd Shallat's *Structures in the Stream* and Donald C. Jackson's *Building the Ultimate Dam*—leave unanswered the spectrum of environmental questions evoked by their otherwise provocative and deeply researched examinations of engineering choices.[66]

One of the most well-developed literatures dealing with water in the United States addresses the damming of Western rivers. Sometimes these water resource histories make little attempt to explain the technological systems involved, and sometimes the environmental impacts are given only cursory treatment. Nevertheless, the very nature of these studies demands that technology and the environment at least appear onstage together. Often, it is political controversy that brings these two variables together.[67] Several studies of individual rivers stand out as exemplars. Philip Scarpino's

66. Robert M. Morgan, *Water and the Land: A History of American Irrigation* (Fairfax, Va., 1993); Todd Shallat, *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (Austin, Tex., 1994); and Donald C. Jackson, *Building the Ultimate Dam: John S. Eastwood and the Control of Water in the West* (Lawrence, Kans., 1995). See also Joseph E. Stevens, *Hoover Dam: An American Adventure* (Norman, Okla., 1988); Mark S. Foster, *Henry J. Kaiser: Builder in the Modern American West* (Austin, Tex., 1989); James R. Kluger, *Turning on Water with a Shovel: The Career of Elwood Mead* (Albuquerque, N. Mex., 1992); Donald E. Wolf, *Big Dams and other Dreams: The Six Companies Story* (Norman, Okla., 1996); and Daniel W. Schneider, "Enclosing the Floodplain: Resource Conflict on the Illinois River, 1880–1920," *Environmental History* 1 (1996): 70–96.

67. A bibliographic treatment of this topic alone would run on for pages. For examples of the most suggestive work, see Philip L. Fradkin, *A River No More: The Colorado River and the West* (New York, 1981; rev. ed., Berkeley, 1996); Abraham Hoffman, *Vision or Villainy: Origins of the Owens Valley–Los Angeles Water Controversy* (College Station, Tex., 1981); Robert G. Dunbar, *Forging New Rights in Western Waters* (Lincoln, Nebr., 1983); Donald J. Pisani, *From the Family Farm to Agribusiness: The Irrigation Crusade in California and the West, 1850–1931* (Berkeley, 1984); Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (New York, 1985); Tim Palmer, *Endangered Rivers and the Conservation Movement* (Berkeley, 1986); Marc Reisner, *Cadillac Desert: The American West and Its Disappearing Water* (New York, 1986); Russell Martin, *A Story That Stands Like a Dam: Glen Canyon and the Struggle for the Soul of the West* (New York, 1989); James Earl Sherow, *Watering the Valley: Development along the High Plains Arkansas River, 1870–1950* (Lawrence, Kans., 1990); Norris Hundley jr., *The Great Thirst: Californians and Water, 1770s–1990s* (Berkeley, 1992); Mark W. T. Harvey, *A Symbol of Wilderness: Echo Park and the American Conservation Movement* (Albuquerque, N. Mex., 1994); and John E. Thorson, *River of Promise: The Politics of Managing the Missouri River* (Lawrence, Kans., 1994). The literature on the development of eastern and southern rivers is much slimmer, although the issues at stake are no less important. See, for example, John M. Kauffmann, *Flow East: A Look at Our North Atlantic Rivers*

history of the Upper Mississippi River, for example, demonstrates great sensitivity toward the push and pull between engineering works and North America's great river. Tim Palmer covers similar ground in his study of the Snake. In a brilliant little book about the Columbia River, the environmental and Western historian Richard White uses the themes of energy and work to explore the rich and varied connections between technology and the environment.[68]

While some historians of water resources development focus on a particular river or project, others concentrate on a particular government agency. At the federal level, the Bureau of Reclamation, Tennessee Valley Authority, and United States Army Corps of Engineers have each been the subject of important histories, all of which shed light (often unintentionally) on some aspect of technology and the environment.[69] Engineers and

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(New York, 1973); Thomas J. Schoenbaum, *The New River Controversy* (Winston-Salem, N.C., 1979); Nelson Manfred Blake, *Land into Water—Water into Land: A History of Water Management in Florida* (Tallahassee, Fla., 1980); Richard C. Albert, *Damming the Delaware: The Rise and Fall of Tocks Island Dam* (University Park, Pa., 1987); John McPhee, *The Control of Nature* (New York, 1989), 3–92; Joel A. Tarr and Robert U. Ayres, "Pollution Trends in the Hudson River and Raritan River Basins, 1790–1980," in *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years,* ed. B. L. Turner II et al. (New York, 1990); Susan Q. Stranahan, *Susquehana, River of Dreams* (Baltimore, 1993); Stine, *Mixing the Waters* (n. 19 above); Harvey H. Jackson III, *Rivers of History: Life on the Coosa, Tallapoosa, Cahaba, and Alabama* (Tuscaloosa, Ala., 1995); and Martin Reuss, *Designing the Bayous: The Control of Water in the Atchafalaya Basin, 1800–1995* (Alexandria, Va., 1998).

68. Philip V. Scarpino, *Great River: An Environmental History of the Upper Mississippi, 1890–1950* (Columbia, Mo., 1985); Tim Palmer, *The Snake River: Window to the West* (Washington, D.C., 1991); and Richard White, *The Organic Machine* (New York, 1995). See also Todd Shallat, ed., *Snake: The Plain and Its People* (Boise, Idaho, 1994); Paul C. Pitzer, *Grand Coulee: Harnessing a Dream* (Pullman, Wash., 1994); Joseph Cone, *A Common Fate: Endangered Salmon and the People of the Pacific Northwest* (New York, 1995); William Dietrich, *Northwest Passage: The Great Columbia River* (New York, 1995); Blaine Harden, *A River Lost: The Life and Death of the Columbia* (New York, 1996); and Tim Palmer, *The Columbia: Sustaining a Modern Resource* (Seattle, 1997).

69. See, for example, Michael C. Robinson, *Water for the West: The Bureau of Reclamation, 1902–1977* (Chicago, 1979); Doris Ostrander Dawdy, *Congress in Its Wisdom: The Bureau of Reclamation and the Public Interest* (Boulder, Colo., 1989); Thomas K. McCraw, *Morgan Versus Lilienthal: A Feud within the TVA* (Chicago, 1970); Erwin C. Hargrove and Paul K. Conkin, eds., *TVA: Fifty Years of Grass Roots Bureaucracy* (Urbana, Ill., 1983); William U. Chandler, *The Myth of TVA: Conservation and Development in the Tennessee Valley, 1933–1983* (Cambridge, Mass., 1984); William Bruce Wheeler and Michael J. McDonald, *TVA and the Tellico Dam, 1936–1979: A Bureaucratic Crisis in Post-Industrial America* (Knoxville, Tenn., 1986); Arthur Maass, *Muddy Waters: The Army Engineers and the Nation's Rivers* (Cambridge, Mass., 1951); Albert E. Cowdrey, "Pioneering Environmental Law: The Army Corps of Engineers and the Refuse Act," *Pacific Historical Review* 46 (1975): 331–49; Daniel A. Mazmanian and Jeanne Nienaber, *Can Organizations Change? Environmental Protection, Citizen Partic-*

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engineering ideology have played influential roles within these government agencies, roles that over time have helped to shape conservation programs, as well as attitudes within the engineering profession itself.[70]

Attempts to control surface water are perhaps more obvious in their technological achievements and environmental impacts than developing underground water sources, yet that story, too, has great importance for both the history of technology and environmental history. John Opie's account of the increasingly sophisticated mining of the High Plains' huge Ogallala aquifer for irrigation purposes provides a case in point.[71] Like groundwater, wetlands have attracted substantial human manipulation but few formal histories. Prior to the European settlement of North America, wetland environments—marshes, swamps, bogs, potholes, bottomlands—covered over 220 million acres of what is today the contiguous United States. Since the colonial era, over 50 percent of those ecosystems has been "reclaimed" for use as agricultural fields, managed forests, building sites, and other purposes. The technologies of draining, filling, diking, and watercourse modification have varied widely over time and from place to place. Ann Vileisis has captured the broad sweep of this monumental reengineering of North America in her compelling environmental history, *Discovering the Unknown Landscape: A History of America's Wetlands,* while Hugh Prince provides a detailed regional study in *Wetlands of the American Midwest.*[72]

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ipation, and the Corps of Engineers (Washington, D.C., 1979); Martin Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering: Politics and Technology in the Army Corps of Engineers, 1850–1950," *Technology and Culture* 26 (1985): 1–33; and Michael C. Robinson, "The Relationship between the Army Corps of Engineers and the Environmental Community, 1920–1969," *Environmental Review* 13 (spring 1989): 1–41.

70. Among the works that touch upon this interplay are Samuel P. Hays, *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890–1920* (Cambridge, Mass., 1959); Donald C. Swain, *Federal Conservation Policy, 1921–1933* (Berkeley, 1963); Jeffrey K. Stine, "Regulating Wetlands in the 1970s: U.S. Army Corps of Engineers and the Environmental Organizations," *Journal of Forest History* 27 (April 1983): 60–75; Carroll Pursell, "Conservation, Environmentalism, and the Engineers: The Progressive Era and the Recent Past," in *Environmental History: Critical Issues in Comparative Perspective,* ed. Kendall E. Bailes (Lanham, Md., 1985), 176–92; and Jamie W. Moore and Dorothy P. Moore, *The Army Corps of Engineers and the Evolution of Federal Flood Plain Management Policy* (Boulder, Colo., 1989).

71. John Opie, *Ogallala: Water for a Dry Land* (Lincoln, Nebr., 1993). See also Donald E. Green, *Land of the Underground Rain: Irrigation on the Texas High Plains, 1910–1970* (Austin, Tex., 1973); and Ronald L. Nye, "Visions of Salt: Salinity and Drainage in the San Joaquin Valley, California, 1870–1970" (Ph.D. diss., University of California, Santa Barbara, 1986).

72. Ann Vileisis, *Discovering the Unknown Landscape: A History of America's Wetlands* (Washington, D.C., 1997); Hugh Prince, *Wetlands of the American Midwest: A Historical Geography of Changing Attitudes* (Chicago, 1997). For earlier accounts of wetlands that paid some attention to reclamation technologies, see Paul L. Errington, *Of*

Given the popularity of "edge environments," where land and water meet, America's coastlines have been subjected to intensive development, along with extensive engineering works to protect those shores from storm damage and erosion. These protective structures all too often have triggered the need for subsequent engineering efforts to restore the beaches that were unwittingly harmed in the process. The environmental consequences of this type of shoreline development have been significant, yet the ecological and geological nuances of those modifications are rarely fully understood or appreciated. Although much remains to be written on the subject, especially for specific locales and for the evolution of state and national policy, several works have addressed the nexus of technology and the environment in this context.[73]

As the United States became increasingly concerned with water quality during the 1960s and thereafter, the connections between technology and the environment gained ever greater relevance from a regulatory and policy perspective.[74] Few historical works provide a better model for the study of the long-term environmental impacts of a particular industry on a particular river than Richard A. Bartlett's treatise on the pulp and paper mills operated by Champion International along the banks of North Carolina's Pigeon River. Bartlett is especially good at interweaving the fluctuations in water pollution levels, the ecological consequences of industrial contaminants, the mix of local and national responses, and the shifts in processing and pollution-control technologies. On a more general level, John G. Burke's 1979

Men and Marshes (New York, 1957); Joseph V. Siry, *Marshes of the Ocean Shore: Development of an Ecological Ethic* (College Station, Tex., 1984); and Kimberly R. Sebold, *From Marsh to Farm: The Landscape Transformation of Coastal New Jersey* (Washington, D.C., 1992). For a study of reclamation technology that conversely downplayed its environmental effects, see Marion M. Weaver, *History of Tile Drainage (In America prior to 1900)* (Waterloo, N.Y., 1964).

73. See, for example, Wallace Kaufman and Orrin H. Pilkey Jr., *The Beaches Are Moving: The Drowning of America's Shoreline* (Durham, N.C., 1983); Susan Pritchard O'Hara and Gregory Graves, *Saving California's Coast: Army Engineers at Oceanside and Humboldt Bay* (Spokane, Wash., 1991); and Orrin H. Pilkey Jr. and Katharine L. Dixon, *The Corps and the Shore* (Washington, D.C., 1996).

74. For examples of critical assessments of the environmental impact of water resources development written by nonhistorians but utilizing historical case studies, see Elizabeth S. Helfman, *Rivers and Watersheds in America's Future* (New York, 1965); Donald E. Carr, *Death of the Sweet Waters* (New York, 1966); Gene Marine, *America the Raped: The Engineering Mentality and the Devastation of a Continent* (New York, 1969); George Laycock, *The Diligent Destroyers* (New York, 1970); Arthur E. Morgan, *Dams and Other Disasters: A Century of the Army Corps of Engineers in Civil Works* (Boston, 1971); Richard L. Berkman and W. Kip Viscusi, *Damming the West* (New York, 1973); Martin Heuvelmans, *The River Killers* (Harrisburg, Pa., 1974); Edward Goldsmith and Nicholas Hildyard, *The Social and Environmental Effects of Large Dams* (San Francisco, 1984); and Constance Elizabeth Hunt and Verne Huser, *Down by the River: The Impact of Federal Water Projects and Policies on Biological Diversity* (Washington, D.C., 1988).

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article "Wood Pulp, Water Pollution, and Advertising" explored the relationships between the vast expansion in printed advertisements, the enlarged production of wood pulp, and pollution of America's rivers and streams.[75]

Large-scale engineering projects that manipulate natural resources in one way or another present telling stories of the interaction between technology, the environment, and societal values. Peter A. Coates, for example, combined the insights and questions of environmental history and the history of technology when examining the history of the 800-mile-long trans-Alaska pipeline, which was built amid fierce controversy in the 1970s. Coates went beyond recounting the political opposition to the pipeline and the project's environmental transgressions and explained how the actual design and construction practices were modified to incorporate at least some of the environmental values then being embraced by society at large. A similar process was at work on another controversial macroengineering project, the Tennessee-Tombigbee Waterway in Mississippi and Alabama. Designed and constructed at the same time as the Alaska pipeline, the waterway is treated in Jeffrey Stine's *Mixing the Waters.* Opponents of these two projects, like adversaries of numerous other large public works of the period, failed in their attempts to terminate them but succeeded in forcing changes that significantly reduced the projects' environmental impacts.[76]

Extractive industries of various sorts constitute another area of natural resources history that has drawn attention to the interaction of technology and the environment. Nathan Rosenberg, for example, has stressed how the economic and social importance of various natural resources is profoundly influenced by shifts in technology. As technologies change, so do the anthropocentric values assigned to specific natural resources: sometimes materials once not considered useful become so after the development of manufacturing technologies to use them (e.g., iron, aluminum, uranium); other times, modestly useful materials gain added value because of improved extractive, processing, and transportation technologies (e.g., low-grade ores, rubber, oil).[77]

75. Richard A. Bartlett, *Troubled Waters: Champion International and the Pigeon River Controversy* (Knoxville, Tenn., 1995); and Burke (n. 16 above). Also useful is Thomas R. Huffman, *Protectors of the Land and Water: Environmentalism in Wisconsin, 1961–1968* (Chapel Hill, N.C., 1994).

76. Peter A. Coates, *The Trans-Alaska Pipeline Controversy: Technology, Conservation, and the Frontier* (Bethlehem, Pa., 1991); and Stine, *Mixing the Waters* (n. 19 above). See also Jeffrey K. Stine, "Environmental Politics and Water Resources Development: The Case of the Army Corps of Engineers during the 1970s" (Ph.D. diss., University of California, Santa Barbara, 1984); and Donald Worster, "Alaska: The Underworld Erupts," in his *Under Western Skies: Nature and History in the American West* (New York, 1992), 154–224.

77. See Rosenberg, *Technology and American Economic Growth* (n. 8 above), 18–24; and Nathan Rosenberg, "Technological Innovation and Natural Resources: The Niggard-

As mentioned, the environmental impact of mining iron ore for the steel industry has yet to be fully explored. Except for Duane A. Smith's perceptive overview, *Mining America: The Industry and the Environment, 1800–1980,* the same could be said about mining in general. The historiographical gap is gradually being filled, however, by a new generation of historians deliberately setting out to document both the technological and the environmental histories of mining and the processing of ores. Timothy J. LeCain recently completed a history of Western copper mining that focused on the extreme environmental costs of open-pit mining, as well as the role of mining engineers in developing pollution-control technologies. Fredric L. Quivik's history of copper smelting in Montana is an exemplary environmental history of a mainline industrial technology. One of the most enlightening models for how technological and environmental variables can be brought to bear in the study of a particular mining operation is provided by William Cronon in his essay on Alaska's Kennecott copper mine.[78]

Few human activities have done more to change the face of the earth than has agriculture. Although agricultural historians have paid only limited attention to technology and the environment as agents of change, this subfield of history has a long tradition and a rich literature that touches upon these forces.[79] In addition to specific studies of agricultural technologies, other topics have included land clearing; drainage; farm pond cre-

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liness of Nature Reconsidered," in *Technological Innovation: A Critical Review of Current Knowledge,* ed. Patrick Kelly and Melvin Kranzberg (San Francisco, 1978), 183–97.

78. Duane A. Smith, *Mining America: The Industry and the Environment, 1800–1980* (Lawrence, Kans., 1987); Timothy J. LeCain, "Moving Mountains: Technology and the Environment in Western Copper Mining" (Ph.D. diss., University of Delaware, 1998); Fredric L. Quivik, "Smoke and Tailings: An Environmental History of Copper Smelting Technologies in Montana, 1880–1930" (Ph.D. diss., University of Pennsylvania, 1998); and William Cronon, "Kennecott Journey: The Paths out of Town," in *Under an Open Sky: Rethinking America's Western Past,* ed. William Cronon, George Miles, and Jay Gitlin (New York, 1992), 28–51. See also Robert L. Kelley, *Gold vs. Grain: The Hydraulic Mining Controversy in California's Sacramento Valley* (Glendale, Calif., 1959); Larry D. Lankton, *Cradle to Grave: Life, Work, and Death at the Lake Superior Copper Mines* (New York, 1991); M. L. Quinn, "Industry and Environment in the Appalachian Copper Basin, 1890–1930," *Technology and Culture* 34 (1993): 575–612; John D. Wirth, "The Trail Smelter Dispute: Canadians and Americans Confront Transboundary Pollution, 1927–41," *Environmental History* 1 (1996): 34–51; and Fredric L. Quivik, "The Historic Landscape of Butte and Anaconda, Montana," in *Images of an American Land: Vernacular Architecture in the Western United States,* ed. Thomas Carter (Albuquerque, N. Mex., 1997), 267–90.

79. Agricultural history once commanded greater attention within SHOT and the pages of *Technology and Culture,* although these earlier works tended to focus on the hardware, not on the environmental effects of technology. This tradition can be seen in C. Clyde Jones and Homer E. Socolofsky, guest editors, "Agricultural History Symposium: Science and Technology in Agriculture," a special issue of *Agricultural*

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ation; fencing; plowing; irrigation; applications of chemical fertilizers, pesticides, fungicides, and herbicides; animal and plant breeding; introduction of exotic species; concentration of animals; and monoculture. All these activities and a hundred others fit into the broader environmental-technological history of agriculture. Recognizing the importance of this human enterprise, Donald Worster has argued that agricultural history can provide a lens for examining environmental history itself.[80] In the reciprocal interactions of technology and the environment over time, agricultural history is full of rich possibilities. To date, much of the best work in this area has focused on specific regions of the country. In *Ecological Revolutions,* for example, Carolyn Merchant provides great insights into the relationships between technology, the environment, and agriculture as they unfolded in New England before 1850. Mart A. Stewart does the same for the Georgia coastal plain prior to 1920, while across the continent Richard White looks at the long historical sweep of the environmental consequences of agricultural practices in Island County, Washington.[81] Worster himself offers a powerful example of how such a study might be done in his Bancroft Prize-winning book, *Dust Bowl: The Southern Plains in the 1930s.* By analyzing the interplay of technology, politics, and ecology, Worster argues that the environmental and economic impact of the dust bowl did not result from a "natural disaster" but was exacerbated, if not created, by the practices of people (agricultural practices that were maladapted to the ecology of the

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History 54 (January 1980). For a guide to this literature, see R. Douglas Hurt and Mary Ellen Hurt, *The History of Agricultural Science and Technology: An International Annotated Bibliography* (New York, 1994).

80. Worster, "Agroecological Perspective in History" (n. 14 above), 1087–106. See also Carville Earle, "The Myth of the Southern Soil Miner: Macrohistory, Agricultural Innovation, and Environmental Change," in *The Ends of the Earth: Perspectives on Modern Environmental History,* ed. Donald Worster (New York, 1988), 175–210; Daniel E. Vasey, *An Ecological History of Agriculture, 10,000 B.C.–A.D. 10,000* (Ames, Iowa, 1992); Frieda Knobloch, *The Culture of Wilderness: Agriculture as Colonization in the American West* (Chapel Hill, N.C., 1996); and Emily W. B. Russell, *People and the Land through Time: Linking Ecology and History* (New Haven, Conn., 1997).

81. Carolyn Merchant, *Ecological Revolutions: Nature, Gender, and Science in New England* (Chapel Hill, N.C., 1989); Mart A. Stewart, *"What Nature Suffers to Groe": Life, Labor, and Landscape on the Georgia Coast, 1680–1920* (Athens, Ga., 1996); and Richard White, *Land Use, Environment, and Social Change: The Shaping of Island County, Washington* (Seattle, 1980). See also James C. Malin, *The Grassland of North America: Prolegomena to Its History* (Lawrence, Kans., 1947); William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York, 1983); Albert E. Cowdrey, *This Land, This South: An Environmental History* (Lexington, Ky., 1983); Timothy Silver, *A New Face on the Countryside: Indians, Colonists, and Slaves in South Atlantic Forests, 1500–1800* (Cambridge, 1990); and Jack Temple Kirby, *Poquosin: A Study of Rural Landscape and Society* (Chapel Hill, N.C., 1995). For parallel perspectives on a regional fishing industry, see Arthur F. McEvoy, *The Fisherman's Problem: Ecology and Law in the California Fisheries, 1850–1980* (Cambridge, 1986).

plains states). He does not place the blame on technology but on the economic motives and values inherent in capitalistic agriculture, which encourages the conquest of nature through technology.[82]

The development of chemical pesticides since World War II has produced a huge industry in the United States, with profound economic—and environmental—consequences. With her landmark book, *Silent Spring,* Rachel Carson raised broad public concern about the public health and ecological consequences of the misuse of these poisons. Several journalists and environmental writers were prompted to follow her lead with studies of their own, as were a handful of historians.[83] Among the last group, James Whorton's examination of early chemical pesticides, Thomas R. Dunlap's treatment of the public policy controversy over DDT, and John H. Perkins's history of alternative pest-control management strategies stand out as exemplars. More recently, Edmund P. Russell has turned his attention to the reciprocal interplay between military technology and the environment with regard to the complementary development of chemical weapons and insecticides.[84]

Landscape studies and historical geography, which typically embrace considerations of natural resources, have also examined the connections between technology and the environment. In this respect, the environment often involves geographical space and overarching spacial relations, while technology often includes various means to define and/or overcome those spaces. These themes were well represented in John R. Stilgoe's influential

82. Donald Worster, *Dust Bowl: The Southern Plains in the 1930s* (New York, 1979). For an extension of this argument, see Donald Worster, *An Unsettled Country: Changing Landscapes of the American West* (Albuquerque, N. Mex., 1994). For an alternative interpretation, see R. Douglas Hurt, *The Dust Bowl: An Agricultural and Social History* (Chicago, 1981).

83. Rachel Carson, *Silent Spring* (Boston, 1962); Robert L. Rudd, *Pesticides and the Living Landscape* (Madison, Wisc., 1964); Frank Graham Jr., *Since Silent Spring* (Boston, 1970); James Whorton, *Before Silent Spring: Pesticides and Public Health in Pre-DDT America* (Princeton, N.J., 1974); Douglas Helms, "Just Lookin' for a Home: The Cotton Boll Weevil and the South" (Ph.D. diss., Florida State University, 1977); Gino J. Marco, Robert M. Hollingworth, and William Durham, eds., *Silent Spring Revisited* (Washington, D.C., 1987); and Christopher J. Bosso, *Pesticides and Politics: The Life Cycle of a Public Issue* (Pittsburgh, 1987). For a full-scale biography of Carson that addresses both the impact of her writings and her various experiences with industrial pollution, see Linda Lear, *Rachel Carson: Witness for Nature* (New York, 1997).

84. Whorton; Thomas R. Dunlap, *DDT: Scientists, Citizens, and Public Policy* (Princeton, 1981); John H. Perkins, *Insects, Experts, and the Insecticide Crisis: The Quest for New Pest Management Strategies* (New York, 1982); Edmund P. Russell III, "War on Insects: Warfare, Insecticides, and Environmental Change in the United States, 1870–1945" (Ph.D. diss., University of Michigan, 1993), and "'Speaking of Annihilation': Mobilizing for War against Human and Insect Enemies, 1914–1945," *Journal of American History* 82 (1996): 1505–29. See also Perkins, "Reshaping Technology in Wartime" (n. 16 above).

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studies *Common Landscape of America* and *Metropolitan Corridor.* Gordon G. Whitney's *From Coastal Wilderness to Fruited Plain* provided a superb overview of the changes brought about by Europeans (and their various technologies and technological systems) on the North American continent, and its discussions of various types of farming and forestry are especially telling.[85] In his influential book *Landscape and Memory,* Simon Schama argued that "[e]ven the landscapes that are supposed to be most free of our culture may turn out, on closer inspection, to be its product."[86] Culture bears on landscape through technologies and technological systems. In *American Technological Sublime,* David E. Nye examined those aspects of the North American landscape that inspired a sense of awe, and he found a close, complex linkage between the wonders of the engineered world and those of the natural one. Another model of this type of study is William Irwin's *The New Niagara,* which analyzed the interplay of technology and the natural environment in the makeover of the Niagara Falls landscape in the quest to attract the nation's growing number of tourists during the late nineteenth and early twentieth centuries.[87]

85. John R. Stilgoe, *Common Landscape of America, 1580 to 1845* (New Haven, Conn., 1982), and *Metropolitan Corridor: Railroads and the American Scene* (New Haven, Conn., 1983); Gordon G. Whitney, *From Coastal Wilderness to Fruited Plain: A History of Environmental Change in Temperate North America, 1500 to the Present* (Cambridge, 1994). For a sample of the contributions of historical geography and landscape studies to our understanding of the reciprocal influences of technology and the environment, see Michael P. Conzen, ed., *The Making of the American Landscape* (New York, 1990); Bret Wallach, *At Odds with Progress: Americans and Conservation* (Tucson, Ariz., 1991); Larry M. Dilsaver and Craig E. Colten, eds., *The American Environment: Interpretations of Past Geographies* (Lanham, Md., 1992); Alexander Wilson, *The Culture of Nature: North American Landscape from Disney to the "Exxon Valdez"* (Cambridge, Mass., 1992); Rutherford H. Platt, Rowan A. Roundtree, and Pamela C. Muick, *The Ecological City: Preserving and Restoring Urban Biodiversity* (Amherst, Mass., 1994); Robert Thayer, *Gray World, Green Heart: Technology, Nature, and the Sustainable Landscape* (New York, 1994); and George F. Thompson, ed., *Landscape in America* (Austin, Tex., 1995). Also useful is Linda Flint McClelland, *Building the National Parks: Historic Landscape Design and Construction* (Baltimore, 1998).

86. Simon Schama, *Landscape and Memory* (New York, 1995), 9. For his observation that England's "natural" landscape was actually man-made, see René Jules Dubos, *So Human an Animal* (New York, 1968).

87. David E. Nye, *American Technological Sublime* (Cambridge, Mass., 1994); and William Irwin, *The New Niagara: Tourism, Technology, and the Landscape of Niagara Falls, 1776–1917* (University Park, Pa., 1996). See also Gail E. H. Evans, "Storm over Niagara: A Study of the Interplay of Cultural Values, Resources Politics, and Environmental Policy in an International Setting, 1670–1950" (Ph.D. diss., University of California, Santa Barbara, 1991); and Pierre Berton, *Niagara: A History of the Falls* (Toronto, 1992).

Environmental Policy and Politics

During the twentieth century, nowhere were technology and the environment more clearly linked than in the realm of environmental policy, which almost always involved technology in one way or another. Determining environmental policy often required the use of technology to prescribe what could or could not be done; to prevent or reduce pollutants (by the "best available technology"); to measure and monitor the natural world, as well as levels of industrial pollution; and to develop techniques and technologies to clean up existing messes. Technology was necessary for a variety of reasons, not least the fact that many of society's environmental problems were caused or exacerbated by technology itself. And as more and more people became concerned about environmental quality after World War II, reform-minded individuals and groups turned to the government to bring about change. Despite this real-world connection between technology and the environment embedded in local and national politics, few historians have plumbed the depths of these interactions within the realm of environmental policy. Most scholarship in this area has been produced by political scientists and journalists.[88]

Reflecting the broader society's concerns, the U.S. Congress became increasingly interested in the environmental and social impacts of technology during the late 1960s and early 1970s. To assist their deliberations, the legislative branch created the United States Congressional Office of Technology Assessment (OTA) in 1972, at the height of the environmental movement and the public attraction to appropriate technology. OTA analysts eventually addressed all kinds of problems—science policy, science and engineering education, food safety, military weaponry, space exploration, and the like—yet, at its heart, the OTA was meant to probe the unintended (and initially unanticipated) consequences of technology. Many of these consequences were environmental in nature. Despite its substantial track record and its contributions to the policy-making

88. See, for example, Lester W. Milbrath, *Environmentalists: Vanguard for a New Society* (Albany, N.Y., 1984); James P. Lester, ed., *Environmental Politics and Policy: Theories and Evidence* (Durham, N.C., 1989); George Hoberg, *Pluralism by Design: Environmental Policy and the American Regulatory State* (New York, 1992); Philip Shabecoff, *A Fierce Green Fire: The American Environmental Movement* (New York, 1993); Robert Gottlieb, *Forcing the Spring: The Transformation of the American Environmental Movement* (Washington, D.C., 1993); Kirkpatrick Sale, *The Green Revolution: The American Environmental Movement, 1962–1992* (New York, 1993); and Daniel J. Fiorino, *Making Environmental Policy* (Berkeley, 1995). The most thorough work by a historian in this area is Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985* (New York, 1987). Also useful is Victor Ferkiss, *Nature, Technology, and Society: Cultural Roots of the Current Environmental Crisis* (New York, 1993).

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process, OTA fell victim to the budget cuts of the 104th Congress, which killed the program in 1995.[89]

In analyzing the impact of technology, "technology assessment," as practiced at OTA and elsewhere, drew upon many disciplines. Some studies were decidedly historical in their orientation, often employing the title "retrospective technology assessment." Our own sense—and one shared by many others inside and outside the OTA—is that the insights of history were not used nearly enough. The practical perspective of good historical work would have been profound for these policy-oriented documents. (No doubt applying such a historical perspective would have contributed significantly to the scholarly study of the history of technology and environmental history.) In part, history was underemployed because the principal consumers of the reports (congressional committees and individual members) did not specifically call for it. Nor did the leadership of OTA, which was drawn overwhelmingly from the sciences and engineering. However, part of the responsibility rests with the historical community, which did not seek out such work or offer many examples consciously attempting to contribute to the policy debate.[90]

The 1970s and 1980s witnessed the publication of many books on environmental policy, but few of them placed the analysis within a historical context. Most focused on the contemporary scene and on solving problems of the decade. The first of these was based on an NSF-funded Conference in Retrospective Technology Assessment, held in cooperation with the Carnegie Mellon University Program in Engineering and Public Policy (now the Department of Engineering and Public Policy) in December 1976. This interdisciplinary and exploratory conference focused on the impacts of technology, intended and unintended, on past society. The purpose was to use history to improve technology assessment and to enlighten present policy in technology-related areas. A disciplinary mix of academics and policy makers attended the conference, the results of which were published the following year.[91]

89. In 1996, the U.S. Government Printing Office issued a CD-ROM set that contained the full text of every OTA report ever issued. See *Office of Technology Assessment CD-ROM* (Washington, D.C., 1996). For a political scientist's evaluation of OTA, see Bruce Bimber, *The Politics of Expertise in Congress: The Rise and Fall of the Office of Technology Assessment* (Albany, N.Y., 1996).

90. See, for example, Lynn White jr., "Technology Assessment from the Stance of a Medieval Historian," *American Historical Review* 79 (February 1974): 1–13; Carroll Pursell, "Belling the Cat: A Critique of Technology Assessment," *Lex et Scientia* 10 (October–December 1974): 130–45; Tarr, *Retrospective Technology Assessment* (n. 34 above); Howard P. Segal, "Assessing Retrospective Technology Assessment: A Review of the Literature," *Technology in Society* 4 (1982): 231–46; Nancy Carson, "Process, Prescience, and Pragmatism: The Office of Technology Assessment," in *Organizations for Policy Analysis: Helping Government Think,* ed. Carol H. Weiss (Newbury Park, Calif., 1992); and Jeffrey K. Stine, *Twenty Years of Science in the Public Interest: A History of the Congressional Science and Engineering Fellowship Program* (Washington, D.C., 1994).

91. See Tarr, *Retrospective Technology Assessment.*

At the same time that technology assessment was attracting advocates in the United States, appropriate technology began generating a similar appeal among a growing segment of Americans. Two books published in 1973, E. F. Schumacher's *Small Is Beautiful* and Ivan Illich's *Tools for Conviviality,* extended popular and scholarly interest in reorienting technology, particularly in ways that were ecologically sound and aimed toward the use of renewable resources. As early as 1979, Carroll Pursell called upon historians of technology to contribute to this search for appropriate technology.[92]

Energy policy by its very nature overlaps with industrial and environmental policy. Although the energy crises of the 1970s prompted a number of energy histories, few historians seeking to analyze the push and pull between technology and the environment have probed the depths of this subject. Exceptions to this trend include Richard Vietor's analysis of the public policy debates over the use of coal, Hugh Gorman's examination of the engineering response to pollution in the petroleum industry, and James Williams's detailed account of California's energy history, which interweaves the relationships between energy, technology, and the environment. Among the publications of political scientists who have outlined the policy ramifications, Walter A. Rosenbaum's *Energy, Politics, and Public Policy* remains one of the most influential studies.[93]

Technology and the environment have also been brought together within various government organizations, which both set and implement

92. E. F. Schumacher, *Small Is Beautiful: Economics as if People Mattered* (New York, 1973); Ivan Illich, *Tools for Conviviality* (New York, 1973); and Carroll W. Pursell Jr., "The History of Technology as a Source of Appropriate Technology," *The Public Historian* 1 (winter 1979): 15–22. For the connections between the environmental and appropriate technology movements, see Charles T. Rubin, *The Green Crusade: Rethinking the Roots of Environmentalism* (New York, 1994). Also useful are Amory B. Lovins, *Soft Energy Paths: Toward a Durable Peace* (New York, 1977); Lane de Moll and Gigi Coe, eds., *Stepping Stones: Appropriate Technology and Beyond* (New York, 1978); Arnold Pacey, *The Culture of Technology* (Cambridge, Mass., 1983); Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago, 1986); Carroll Pursell, "The Rise and Fall of the Appropriate Technology Movement in the United States, 1965–1985," *Technology and Culture* 34 (1993): 629–37; and Jordan Kleiman, "The Appropriate Technology Movement in American Political Culture" (Ph.D. diss., University of Rochester, expected 1998).

93. Richard H. K. Vietor, *Environmental Politics and the Coal Coalition* (College Station, Tex., 1980); Hugh S. Gorman, "From Conservation to Environment: The Engineering Response to Pollution Concerns in the U.S. Petroleum Industry, 1921–1981" (Ph.D. diss., Carnegie Mellon University, 1996); James C. Williams, *Modern California* (n. 19 above); and Walter A. Rosenbaum, *Energy, Politics, and Public Policy,* 2d ed. (Washington, D.C., 1987). See also Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (New York, 1980); George H. Daniels and Mark H. Rose, eds., *Energy and Transport: Historical Perspectives in Policy Issues* (Beverly Hills, Calif., 1982); Melosi, *Coping with Abundance* (n. 35 above); and J. Samuel Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment, 1963–1971* (Berkeley, 1992).

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policy. Perhaps the most obvious agencies are those dealing with natural resources (such as the United States Army Corps of Engineers, Tennessee Valley Authority, Bureau of Reclamation, Department of Agriculture, Forest Service), which are discussed elsewhere in this essay. The United States Environmental Protection Agency (EPA) falls outside this category, dealing as it has with environmental quality generally but more specifically with environmental quality as it influences human health. Through the establishment of technology-based standards and the allocation of billions of dollars for pollution control and regulation, EPA has had a profound influence on the dissemination and adoption of various types of environmental technologies. Despite the importance of this federal agency for both environmental history and the history of technology, however, few historians have studied its past. Unfortunately, EPA's establishment of an internal office of history in the early 1990s was short-lived, as it fell victim—like OTA—to the federal downsizing of the past few years.[94]

Concluding Thoughts and Future Directions

Historians of technology have only recently begun to explore the interaction of technology and the environment in a sustained way. The reasons for their neglect of this important question, or set of questions, are various. For many years, the history of technology focused on technological "progress," while paying scant attention to technology's broader societal consequences. Initial challenges to this orthodoxy introduced considerations typically associated with the new social history; the inclusion of environmental factors is simply an extension of this trend. One limiting factor to the study of technology and the environment is its failure thus far to attract a scholarly entrepreneur on a par with Melvin Kranzberg, longtime advocate for the history of technology. Another is the academic reward system, which favors easily categorized work, not research that occupies the gray areas between established fields.[95] Because environmental history is

94. For general works on the agency, see John Quarles, *Cleaning Up America: An Insider's View of the Environmental Protection Agency* (Boston, 1976); Bruce A. Ackerman and William T. Hassler, *Clean Coal/Dirty Air: Or How the Clean Air Act Became a Multibillion-Dollar Bail-Out for High-Sulfur Coal Producers and What Should Be Done about It* (New Haven, Conn., 1981); Robert F. Durant, *When Government Regulates Itself: EPA, TVA, and Pollution Control in the 1970s* (Knoxville, Tenn., 1985); Marc K. Landy, Marc J. Roberts, and Stephen R. Thomas, *The Environmental Protection Agency: Asking the Wrong Questions* (New York, 1990); Joel A. Mintz, *Enforcement at the EPA: High Stakes and Hard Choices* (Austin, Tex., 1995); and Edmund P. Russell III, "Lost among the Parts per Billion: Ecological Protection at the United States Environmental Protection Agency, 1970–1993," *Environmental History* 2 (1997): 29–51.

95. The history of technology experienced a similar dilemma prior to SHOT's establishment.

itself a relatively new field, it, too, has only recently begun to branch out. Moreover, environmental historians have frequently held a bias against technology, which skewed their selection of research topics. A reverse bias has undoubtedly been at play among many historians of technology.

As these barriers to the study of technology and the environment weaken, historians of technology can be expected to care more about environmental variables for a number of reasons. First and foremost, they ought to care because society cares—that is, environmental quality ranks high on the nation's scale of values. Just as historians have expanded the boundaries of their analysis in response to major areas of social concern (witness the development of labor history, women's history, and African American history, for example), historians of technology have a special obligation to write about environmental problems because their particular skills and experience offer invaluable insights into this area of global concern. Historians of technology should also incorporate environmental dimensions in their studies to foster richer, more complex histories.

Although some senior historians have addressed topics involving the intersection of technology and the environment, much of the current work is being pursued by doctoral candidates and recent Ph.D.'s, who will be completing their dissertations and book projects over the course of the next few years.[96] Nevertheless, this fertile field of inquiry has been only barely explored. Topics ripe for historical analysis include the proliferation of environmental legislation (such as technology-forcing regulations) since the 1960s and its impact on industry; the life cycles of various industries and the environmental effects of their products; the development of pollution-control technologies; the environmental consequences of military technology and war; the establishment of various environmental standards and indicators; and the evolution of the profession of environmental engineering.

96. See, for example, Russell, "War on Insects" (n. 84 above); Gorman, "From Conservation to Environment"; LeCain (n. 78 above); Quivik, "Smoke and Tailings" (n. 78 above); Lynne Page Snyder, "'The Death-Dealing Smog over Donora, Pa': Industrial Air Pollution, Public Health, and Federal Policy, 1915–1963" (Ph.D. diss., University of Pennsylvania, 1994); Marguerite S. Shaffer, "See America First: Tourism and National Identity, 1905–1930" (Ph.D. diss., Harvard University, 1994); Nicholas A. Casner, "Acid Water: A History of Coal Mine Pollution in Western Pennsylvania, 1880–1950" (Ph.D. diss., Carnegie Mellon University, 1994); Jeffrey Charles Ellis, "When Green Was Pink: Environmental Dissent in Cold War America" (Ph.D. diss., University of California, Davis, 1995); Adam Rome, "Prairie Creek Hills Estates: An Environmental History of American Homebuilding, 1945–1970" (Ph.D. diss., University of Kansas, 1996); David G. Hendricks, "Conservation's End: Resource Development in the Age of Ecology, 1957–1982" (Ph.D. diss., University of California, Davis, 1998); Barbara L. Allen, "Language, Identity, and Place: Strategizing Community Change in Louisiana's Cancer Alley" (Ph.D. diss., Rensselaer Polytechnic Institute, expected 1998); and Betsy Mendelsohn, "Urban Quagmire: Law, Industry, and Chicago's Wetlands, 1820–1920" (Ph.D. diss., University of Chicago, expected 1999).

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Christine Meisner Rosen recently argued that the environmental impacts of industry "are as much a part of the natural ecology of our industrial system as those generated by resource extraction and manufacturing," and that business historians should therefore view business-environment-society interrelationships as an "integral part of business history."[97] This statement runs parallel to our own plea to historians of technology. Although historians of technology have been more sensitive to environmental issues and relationships than have business historians, our survey has shown that too many authors still give short shrift to environmental variables. Clearly, however, the new generation of historians will increasingly include environmental factors as necessary components in analyzing the role of technology in society.

97. Christine Meisner Rosen, "Industrial Ecology and the Greening of Business History," *Business and Economic History* 26 (fall 1997): 123–37.